NUCLEAR INFRASTRUCTURE NONPROLIFERATION IMPACT ASSESSMENT

For Accomplishing Expanded Civilian Nuclear Energy Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility

September 2000

United States Department of Energy
Office of Arms Control and Nonproliferation

EXECUTIVE SUMMARY

ES-1 PURPOSE, SCOPE, AND OBJECTIVE

This document assesses the potential nonproliferation impacts that might result from U.S. Department of Energy (hereafter referred to as the Department or DOE) nuclear infrastructure improvements as proposed and described in the *Draft Programmatic Environmental Impact Statement for Accomplishing Expanded Civilian Nuclear Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility* (DOE/EIS 0310D), July, 2000 (hereafter referred to as the Draft NI PEIS). The DOE Office of Arms Control and Nonproliferation has prepared this *Nuclear Infrastructure Nonproliferation Impact Assessment for Accomplishing Expanded Civilian Nuclear Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility* (hereafter referred to as the NI NIA). Together with the Draft NI PEIS and an associated cost report, both being prepared by the DOE Office of Nuclear Energy, this assessment is being made available to the public as part of the Department's decision-making process to evaluate nuclear infrastructure improvement alternatives.

The United States has an annual requirement for the production of radioisotopes needed for medical, industrial, and scientific applications. The Department has an obligation to supply Pu-238 thermal/power supplies to support currently scheduled and future NASA missions. Civil nuclear energy research and development (R&D) is also required to support future U.S. nuclear energy production, civil nuclear waste disposal, and possible nuclear science applications (*e.g.,* space reactors for future NASA missions). These programmatic needs, particularly those emanating from the projected growth rate in the use of medical isotopes and the continued requirement to produce isotopes for other applications (*e.g.,* Pu-238 for NASA missions), have led the Department to consider various infrastructure improvement alternatives, including the utilization of existing and new facilities.

The Department issued a Notice of Intent on September 15, 1999 to prepare a PEIS for specified alternatives to accomplish these nuclear infrastructure missions.[1] The Notice of Intent identified alternatives as follows: 1) resume Fast Flux Test Facility (FFTF) operation; 2) construct and operate a new research reactor at a generic DOE site; 3) construct and operate one or more new neutron-producing accelerators at a generic DOE site; or 4) meet these projected mission needs utilizing existing reactor and accelerator facilities (other than FFTF). The Draft NI PEIS assesses the environmental impact of all these alternatives, though not in precisely this order. Furthermore, the Draft NI PEIS also evaluates a No Action Alternative and a fifth alternative: permanently deactivate FFTF with no new missions at any U.S. facilities. This NI NIA will follow the same delineation of alternatives as the Draft NI PEIS to assess the nonproliferation impact of actions that are proposed in the Draft NI PEIS.

The objective of the NI NIA is to evaluate the relationship between the missions, facilities, alternatives and options as described in the Draft NI PEIS, and the body of U.S. Government nonproliferation policy, U.S. laws and regulations, and international agreements. Based on that evaluation, the NI NIA presents conclusions and recommendations regarding the nonproliferation merits and drawbacks of the various activities proposed in the Draft NI PEIS to assist the Secretary of Energy to render a Record of Decision following publication of the Final NI PEIS.

[1] "Notice of Intent To Prepare a Programmatic Environmental Impact Statement for Accomplishing Expanded Civilian Nuclear Energy Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility," 64 *Fed. Reg.* 50064, 1999.

This assessment is limited to an evaluation of the direct and reasonably implied nonproliferation impact of the activities proposed in the Draft NI PEIS. Mission necessity, safety, environmental impact, effectiveness, costs, and life-cycle economics of activities described in the Draft NI PEIS are not considered to be central to the nonproliferation analysis reported in the NI NIA.

ES-2 FACILITIES, ALTERNATIVES, AND OPTIONS

The facilities identified by the Department in the Draft NI PEIS are presented in Table ES-1. The irradiation facilities are described and evaluated in Sections 4 and 5 and target fabrication and processing facilities are described and evaluated in Section 6. The facility type, name, location, acronym assigned in the NI NIA, and the operational status of each facility is shown in the table.

Table ES-1. Facilities Identified in the Draft NI PEIS

Type	Name	Acronym	Location	Status
Irradiation	Fast Flux Test Facility	FFTF	Hanford, WA	Standby
	Advanced Test Reactor	ATR	Idaho National Energy and Environmental Laboratory (INEEL), ID	Operational
	High Flux Isotope Reactor	HFIR	Oak Ridge National Laboratory (ORNL), TN	Operational
	Commercial Light Water Reactor	CLWR	Existing CLWR site to be determined	Operational
	New High-Energy Accelerator New Low-Energy Accelerator	- -	Existing DOE site to be determined	- -
	New Research Reactor	-	Existing DOE site to be determined	-
Target Fabrication and Processing	Radiochemical Engineering Development Center	REDC	Oak Ridge National Laboratory (ORNL), TN	Operational
	Fluorinel Dissolution Process Facility CPP-651	FDPF CPP-651	Idaho National Energy and Environmental Laboratory (INEEL), ID	FDPF: Non-operational Available CPP-651: Operational
	Fuels and Materials Examination Facility	FMEF	Hanford, WA	Non-operational Available
	Radiochemical Processing Laboratory Building 306-E	RPL 306-E	Hanford, WA	Operational
	New Support Facility	-	Existing DOE site to be determined	-

Using the facilities identified above, the Department has defined five potential alternatives and a No-Action Alternative to accomplish the missions described above. Table ES-2 defines the five alternatives and enumerates the options under each alternative (*i.e.*, the facility variations within each alternative). Each alternative and option is evaluated in Section 8. Under the No Action Alternative (all options) and Alternative 5, Pu-238 is purchased from Russia to meet NASA program requirements. Furthermore, under all options in Alternatives 2, 3, 4 and 5, FFTF is permanently deactivated. FFTF standby/deactivation is covered by a previous NEPA action that is not evaluated in this assessment, but the standby/deactivation activity is covered as a special case under the comprehensive FFTF nonproliferation assessment given in Section 4.[2]

[2] *Environmental Assessment – Shutdown of the Fast Flux Test Facility, Hanford Site, Richland, Washington,* DOE/EIA-0993, May, 1995.

Table ES-2. Alternatives and Options Defined in the Draft NI PEIS

Alternatives	Options	Irradiation Facility	Pu-238 Production Mission		Medical and Industrial Isotope Production and Nuclear Energy Research and Development Mission	
			Storage Facility	*Processing Facility*	*Storage Facility*	*Processing Facility*
No Action Alternative[d, e]	1	-	-	-	-	-
	2	-	REDC	-	-	-
	3	-	CPP-651	-	-	-
	4	-	FMEF	-	-	-
Alternative 1: *Restart FFTF*[g]	1	FFTF[a]	REDC	REDC	RPL/306-E	RPL/306-E
	2	FFTF[a]	FDPF/CPP-651	FDPF	RPL/306-E	RPL/306-E
	3	FFTF[a]	FMEF	FMEF	FMEF	FMEF
	4	FFTF[b]	REDC	REDC	RPL/306-E	RPL/306-E
	5	FFTF[b]	FDPF/CPP-651	FDPF	RPL/306-E	RPL/306-E
	6	FFTF[b]	FMEF	FMEF	FMEF	FMEF
Alternative 2: *Use Only Existing Operational Facilities*[f]	1	ATR	REDC	REDC	-	-
	2	ATR	FDPF/CPP-651	FDPF	-	-
	3	ATR	FMEF	FMEF	-	-
	4	CLWR	REDC	REDC	-	-
	5	CLWR	FDPF/CPP-651	FDPF	-	-
	6	CLWR	FMEF	FMEF	-	-
	7	HFIR/ATR	REDC	REDC	-	-
	8	HFIR/ATR	FDPF/CPP-651	FDPF	-	-
	9	HFIR/ATR	FMEF	FMEF	-	-
Alternative 3: *Construct New Accelerators*[f, g, h]	1	New	REDC	REDC	New[c]	New[c]
	2	New	FDPF/CPP-651	FDPF	New[c]	New[c]
	3	New	FMEF	FMEF	New[c]	New[c]
Alternative 4: *Construct New Research Reactor*[f]	1	New	REDC	REDC	New[c]	New[c]
	2	New	FDPF/CPP-651	FDPF	New[c]	New[c]
	3	New	FMEF	FMEF	New[c]	New[c]
Alternative 5: *Permanently Deactivate FFTF (with no new missions)*[d]	-	-	-	-	-	-

a) FFTF operates with MOX fuel for 21 years and uranium fuel for 14 years.
b) FFTF operates with MOX fuel for 6 years and uranium fuel for 29 years.
c) The New Support Facility would not be required if a DOE site with available support capability and infrastructure is selected.
d) Under the No Action Alternative (all options) and Alternative 5, Pu-238 is purchased from Russia to supply NASA programs.
e) Under the No Action Alternative, FFTF is maintained in standby mode indefinitely.
f) Under Alternatives 2, 3, and 4, the FFTF is permanently deactivated.
g) The ATW placeholder is not evaluated in this NI NIA. The ATW program will be the topic of a future ATW NIA.
h) A new low-energy accelerator might also be combined with reactor options under Alternative 2 to fulfill all proposed missions.

ES-3 NUCLEAR MATERIALS RELEVANT TO THIS ASSESSMENT

Mixed Oxide Reactor Fuel. Fresh and spent mixed oxide (MOX) fuel contains plutonium isotopes that are immediately useful as a fissile material in nuclear weapons following chemical separation from the uranium contained in the fuel matrix and metallurgical processing. MOX fuel (PuO_2 mixed with UO_2 in sintered pellet form) is intended as the initial fuel supply for the FFTF in the event that a Record of

Decision directs FFTF to restart. Two sources of fresh MOX fuel for FFTF have been identified in the Draft NI PEIS:

- FFTF MOX fuel currently stored at the Hanford site that was remaining when FFTF went into standby mode. There is enough Hanford MOX fuel to operate the reactor at 100 megawatts thermal (MWt) for about 6 years. This fuel is hereafter referred to as Hanford MOX fuel.
- Partially remanufactured German SNR-300 MOX fuel currently stored at Hanau, Germany and Dounreay, Scotland. This fuel would require some remanufacturing and would be imported to the United States for use in the FFTF. There is enough German SNR-300 MOX fuel to operate the FFTF at 100 MWt for about 15 years following the consumption of the Hanford MOX fuel. This fuel is hereafter referred to as German MOX fuel.

Highly Enriched Uranium Reactor Fuel. All uranium enriched in U-235 to or above 20% is called highly enriched uranium (HEU). HEU is special nuclear material (SNM). HEU fuel is required to operate two of the irradiation facilities proposed in the Draft NI PEIS: the High-Flux Isotope Reactor (HFIR) and the Advanced Test Reactor (ATR). Both research reactors use aluminum clad HEU plate fuel. The HEU contained in the HFIR and ATR plate fuel is 93% enriched such that it is immediately useful as a fissile material in nuclear weapons following chemical separation from the fuel matrix and metallurgical processing.

HEU fuel may be required to operate FFTF following the consumption of available MOX fuel supplies. FFTF can use HEU oxide fuel in the form of sintered pellets. The HEU contained in the FFTF oxide fuel is enriched to between 30 and 37%. International and domestic safeguards regulations treat uranium, that is enriched above 20%, as material that is usable as fissile material for nuclear weapons. However, higher assays are more readily usable than lower assays.

Low Enriched Uranium Reactor Fuel. Any uranium enriched in U-235 to less than 20% is called low enriched uranium (LEU). LEU is SNM. LEU fuel is required to operate two of the irradiation facilities proposed in the Draft NI PEIS: commercial light water reactor (CLWR) and new research reactor. A CLWR uses sintered LEU oxide fuel pellets enriched to between 3 and 4%. A new research reactor would use aluminum clad LEU oxide plate fuel enriched to slightly below 20%. In both cases, conversion to uranium hexafluoride, further enrichment and metallurgical processing would be required to obtain material that is readily usable for nuclear weapons.

In fiscal year 2001, the Department's RERTR program plans to study conversion of ATR to use LEU fuel. If a Record of Decision directs a restart of FFTF, the RERTR program will study the conversion of FFTF to LEU fuel. In both cases, If LEU fuel is found to be technically feasible, it would probably be enriched to slightly less than 20%. LEU fuel would require conversion to uranium hexafluoride, further enrichment and metallurgical processing to obtain material that is readily usable for nuclear weapons.

Neptunium. Neptunium is an alternate nuclear material (ANM). The utility of ANM in nuclear weapons is recognized by the U.S. Government and the international community. The Pu-238 production mission described in the Draft NI PEIS requires the production and irradiation of neptunium targets. Neptunium targets are typically made of purified, concentrated neptunium dioxide with an aluminum binder, canned or clad in aluminum. The production of Pu-238 requires the production of purified neptunium dioxide from neptunium solution followed by target fabrication, irradiation to build in Pu-238, chemical processing to separate and purify neptunium and Pu-238 from fission products and other waste products, and a repeat of the cycle to produce further Pu-238. Each cycle destroys neptunium since neptunium is converted to Pu-238 in the process.

Plutonium-238. Pu-238 is special nuclear material (SNM). However, isotopically concentrated Pu-238 (above 80%) is generally recognized to not constitute a nuclear proliferation threat. The IAEA exempts plutonium that contains more than 80% Pu-238 from international safeguards and DOE assigns this material to the lowest DOE safeguards grade. However, this material is rigorously protected against loss, theft and sabotage (through physical protection and accounting) and is strictly contained (to prevent accidental release) as a result of the health and safety risks presented by the material.

Target and Product Materials Associated with Isotope Production Missions. A wide variety of materials (radioactive and nonradioactive) are described in the Draft NI PEIS to produce targets for the production of medical and industrial isotopes. None of the materials listed as targets or products are materials of nuclear nonproliferation concern. As such, these materials are not relevant to this NI NIA.

Civil Nuclear Energy Research and Development Materials. The nuclear materials that might be involved in civil nuclear energy R&D are not described, or listed in detail in the Draft NI PEIS. However, example missions are described. This NI NIA focuses on the use of materials of nonproliferation concern (nuclear weapons-usable fissile materials: plutonium,[3] HEU and ANM) in facilities, alternatives, and options described in the Draft NI PEIS. Civil nuclear energy R&D studies on materials other than the materials of concern are not germane to this NI NIA.

ES-4 NONPROLIFERATION POLICY CONTEXT

In broad terms, the analysis performed in this assessment focuses on four major proliferation concerns that may be raised by the nuclear facilities and operations reviewed in the Draft NI PEIS:

- The concern that, pursuant to the Draft NI PEIS, the construction or operation of a facility in the United States that uses weapons-usable nuclear materials might encourage the development of similar facilities abroad, to the detriment of U.S. non-proliferation efforts aimed at discouraging the development of such facilities;
- The risk that weapons-usable nuclear material might be stolen from a U.S. nuclear facility constructed or operated pursuant to the Draft NI PEIS by agents of a country of proliferation concern or by a subnational organization or terrorist group;
- The risk that restrictions on voluntary or legally mandated international monitoring of certain U.S. facilities operated pursuant to the Draft NI PEIS might reduce confidence in U.S. pledges that it will never use for nuclear weapons certain weapons-usable nuclear materials that it has declared to be excess to defense needs; and
- The risk that activities proposed under the Draft NI PEIS might interfere with the implementation of anticipated future treaties, such as the Fissile Material Cutoff Treaty (FMCT).

The three weapons-usable nuclear materials whose use and processing are analyzed in this assessment, and which are discussed below, are HEU, plutonium,[4] and neptunium. Although HEU and plutonium have long been the subject of U.S. and international nonproliferation controls, neptunium, which to date has been separated in significant quantities only in nuclear-weapon states, became the subject of international regulation only in 1999.

The United States has long led global efforts to prevent the proliferation of nuclear weapons and to safeguard weapons-usable fissile materials against the risk of theft or diversion. Because the knowledge needed to make at least a crude nuclear weapon is now widespread, limited access to these essential

[3] The term “plutonium” is understood in this context to mean isotopic mixtures of plutonium other than isotopically concentrated Pu-238.
[4] Ibid.

ingredients of nuclear weapons is the principal technical barrier to nuclear proliferation in the world today. Hence, the United States has placed heavy emphasis on efforts to help monitor, protect, control, account for, and, ultimately, dispose of weapons-usable fissile materials worldwide.

Because of its pivotal role in preventing the proliferation of nuclear weapons and its own extensive nuclear programs and activities, the manner in which the United States manages its nuclear activities has a significant influence on other states. U.S. technical and policy choices frequently affect similar choices in other countries both by example and in the way these choices support U.S. diplomatic efforts. Thus, decisions of the type analyzed in the Draft NI PEIS that are taken in the United States can positively or negatively affect efforts to enhance the global nonproliferation regime and bolster the international norm against the acquisition of nuclear weapons. In recent years, the United States has sought to make its nuclear activities increasingly transparent in order to increase international confidence in the global arms control and nonproliferation regime and to encourage similar actions by other countries.

In order to practically evaluate the nonproliferation merits and drawbacks of the activities proposed in the Draft NI PEIS, this NI NIA analyzes the proposed missions, facilities, alternatives, and options within the context of U.S. nonproliferation policy. This body of policy is articulated in President Clinton's 1993 Nonproliferation and Export Control Policy Statement (see Appendix 10.2), other relevant U.S. laws and regulations, and international agreements. Most central to this assessment are policies concerning:

- Plutonium reprocessing;
- Civil use of HEU;
- Monitoring of ANM; and
- Support of anticipated FMCT negotiations.

ES-5 NONPROLIFERATION ASSESSMENT METHODS

Technical and Policy Factors. This NI NIA evaluates the nonproliferation impact of the activities proposed in the Draft NI PEIS by analyzing the various missions, facilities, alternatives, and options against three technical factors and four policy factors. The technical evaluation factors focus on assuring that weapons-usable fissile materials are physically difficult to either steal or divert, and that this material and associated processes are appropriately safeguarded. The three technical factors assess the degree to which an activity would be:

- Assuring against theft or diversion;
- Facilitating cost-effective international monitoring; and
- Resulting in final material forms from which retrieval is more difficult than from original material forms.

The four policy factors used in this assessment focus on the ability of the United States to maintain and strengthen international efforts to stem the spread of nuclear weapons, including the overall approach to limit, restrict, and minimize the use of weapons-usable fissile material in civilian applications. Furthermore, the policy factors also address the continued transparency of the U.S. domestic moratorium on fissile material production for nuclear weapons. The four policy factors include the degree to which an activity would be:

- Maintaining consistency with U.S. nonproliferation policy;
- Avoiding encouragement of plutonium reprocessing;
- Building confidence that the United States is not producing material for nuclear weapons; and

- Supporting negotiation of a verifiable Fissile Material Cutoff Treaty.

Evaluation Grading Scale. A qualitative grading scale on three levels is defined to indicate the degree to which particular missions, facilities, alternatives, or options meet U.S. nonproliferation objectives. The three levels in the grading scale are:

● *Fully Meets Nonproliferation Objectives.* A mission, facility, alternative, or option under a factor assessment *fully meets nonproliferation objectives* if: there *are no significant identified concerns* that can be raised demonstrating how the use of the facility or implementation of the alternative is contrary to U.S. nonproliferation objectives as defined by the assessment factor.

◑ *Might Raise Nonproliferation Concerns.* A mission, facility, alternative, or option under a factor assessment *might raise nonproliferation concerns* if: there *is significant uncertainty* as to whether the use of the facility or implementation of the alternative *might have an adverse effect* on U.S. nonproliferation objectives as defined by the assessment factor.

○ *Raises Nonproliferation Concerns.* A mission, facility, alternative, or option under a factor assessment *raises nonproliferation concerns* if: there *are significant identified concerns* that can be raised demonstrating how the use of the facility or implementation of the alternative is contrary to U.S. nonproliferation objectives as defined by the assessment factor.

ES-6 SUMMARY OF NONPROLIFERATION ASSESSMENTS

Table ES-3 shows the summary of the detailed facility assessment scores. Facilities and mission cases (*e.g.,* FFTF standby/deactivation, neptunium storage) are shown across rows and nonproliferation assessment technical and policy factors are shown down columns. *There are currently no U.S. nonproliferation policies, laws, regulations or international agreements that preclude the use of any of the facilities in the manner described in the Draft NI PEIS.* However, there are a few instances of nonproliferation concerns and uncertainties.

These concerns and uncertainties are associated with the use of processing facilities to recover Pu-238 and neptunium from irradiated neptunium targets as part of the Pu-238 production mission. In all facility cases (REDC, FDPF, and FMEF), the repeated separation and purification of neptunium (which is an unavoidable part of the process) raises *significant uncertainty* under the third technical factor associated with reduction in material attractiveness. This is always the case and is technically unavoidable (even if Pu-238 is purchased from Russia, this process is required in a Russian nuclear facility).

Other concerns and uncertainties surrounding the use of FDPF stem from concerns about transparency measures that could be required as part of an FMCT verification regime. The extent to which FDPF, as a former defense nuclear material production facility, would be available for international monitoring under an FMCT is currently unknown.

Irradiation facilities and missions, as described in the Draft NI PEIS, do not have any identified nonproliferation concerns or uncertainties. Although the intended fuel supply for FFTF includes two different sources for existing MOX fuel, an analysis of these MOX supply options identified significant mitigating factors that indicated substantial nonproliferation benefits to disposing of that attractive material as highly radioactive spent fuel (see Section 4). If HEU fuel is required for either FFTF (30 to 37% enriched) or ATR (93% enriched) it will be procured in strict accordance with U.S. nonproliferation policy following the principles outlined in the Schumer Amendment (see Appendix 10.3). The Schumer amendment places restrictions on the export of HEU, requiring that facilities pursue conversion to LEU fuels and targets.

It should be added that operation of the FFTF does not set a precedent that may encourage other states to build new high-flux test reactors using MOX or HEU fuels. The FFTF case is unique: it involves an existing, previously operated facility and the irradiation of previously fabricated MOX fuel now in storage, conditions that are highly unlikely to arise elsewhere. Possible future use of HEU at the facility will be subject to the same strict scrutiny that the United States would wish to have applied by other states considering the use of such fuel.

Table ES-3. Assessments of Facilities as Described in the Draft NI PEIS

		Irradiation Facilities								***Target Fabrication and Processing Facilities***						***Np-237 Storage***		
		FFTF Restarted	FFTF Standby/Deactivated	ATR	HFIR	CLWR	New Low-Energy Accelerator	New High-Energy Accelerator	New Research Reactor	REDC	FDPF	FMEF	RPL	306-E	New Support Facility	REDC	CPP-651	FMEF
Technical Factors	Assuring Against Theft or Diversion	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Facilitating Cost-Effective International Monitoring	●	●	●	●	●	●	●	●	●	○	●	●	●	●	●	●	●
	Resulting in Final Material Forms from which Retrieval is More Difficult than from Original Material Forms	●	●	●	●	●	●	●	●	◑	◑	◑	●	●	●	●	●	●
Policy Factors	Maintaining Consistency with U.S. Nonproliferation Policy	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Avoiding Encouragement of Plutonium Reprocessing	●	●	●	●	●	●	●	●	●	◑	●	●	●	●	●	●	●
	Building Confidence that the U.S. is not Producing Material for Nuclear Weapons	●	●	●	●	●	●	●	●	●	◑	●	●	●	●	●	●	●
	Supporting Negotiation of a Verifiable FMCT	●	●	●	●	●	●	●	●	●	○	●	●	●	●	●	●	●

● *Fully meets nonproliferation objectives*
◑ *Might raise nonproliferation concerns*
○ *Raises nonproliferation concerns*

It should also be noted that although the ATR's defense program mission precludes it from international monitoring, there are no U.S. nonproliferation policy directives, international agreements or regulations that generically prevent civil programs from being conducted in current or former defense facilities –

ATR is currently hosting civil radioisotope production programs. However, when comparable alternatives exist that allow civil programs to be hosted in facilities that are eligible for international monitoring, it is preferable to maintain a separation between defense and civil programs.

Table ES-4 shows the detailed assessment grades for each alternative and option described in the Draft NI PEIS (the alternatives and options are shown in Table ES-2). The alternative and option assessments are performed using the methods described in Section 3 (incorporating each of the facility assessments with a generic transportation assessment in a "weak link" analysis). The generic transportation assessment (see Section 8.3) found no significant nonproliferation impact associated with nuclear material transportation.

In Alternatives 1 through 4 (U.S. Pu-238 production alternatives) the assessments are fully determined by the Pu-238 processing facility assessment (REDC, FDPF, and FMEF). Furthermore, under the No Action Alternative and Alternative 5, the alternative assessments are determined by a generic assessment of the Russian Pu-238 purchase option (presented in Section 8.2). The Russian Pu-238 purchase option suffers from similar nonproliferation uncertainties and concerns as FDPF. In addition, the status of Russian domestic safeguards of ANM is largely unknown. Moreover, since there is currently no Russian moratorium on spent fuel reprocessing, and neptunium recovery is part of the Russian reprocessing flowsheet, the Russian inventory of separated weapons-usable neptunium could continue to increase, even if smaller quantities of neptunium were destroyed in the production of Pu-238.

ES-7 CONCLUSIONS AND RECOMMENDATIONS

ES-7.1 OVERALL ASSESSMENT OF MISSIONS PROPOSED IN THE DRAFT NI PEIS

There are currently no U.S. nonproliferation policies, laws, regulations or international agreements that preclude the use of any of the facilities in the manner described in the Draft NI PEIS. The overall missions (independent of selected facilities) proposed in the Draft NI PEIS are evaluated by using the methods presented in Section 3.

Medical, Industrial, and Research Isotope Production. There *are no significant identified concerns* demonstrating how, within the bounds of the description given in the Draft NI PEIS, the pursuit of the medical, industrial, and research isotope production mission is contrary to U.S. nonproliferation objectives as defined by any assessment factor. Therefore, this mission is graded as ● *fully meets nonproliferation objectives.*

Plutonium-238 Production. With the exception of the third technical assessment factor, *reduction in attractiveness of material forms* (see Section 3), there *are no significant identified concerns* demonstrating how, within the bounds of the description given in the Draft NI PEIS, the pursuit of the Pu-238 production mission is contrary to U.S. nonproliferation objectives as defined by the remaining technical and policy assessment factors. Therefore, these remaining factors are graded as ● *fully meets nonproliferation objectives.* In the case of the third technical assessment factor, the process of producing, recovering, and purifying Pu-238 requires that neptunium also be recovered, purified, and recycled. However, in the event that Pu-238 production is resumed in the United States, the total separated stocks of neptunium will be reduced over time in an irreversible manner since there is a moratorium on U.S. spent fuel reprocessing – the activity that could lead to the production of additional stocks of separated neptunium. This overall reduction in a weapons-usable material stock is a partial mitigation of the identified concern. Even so, *there is significant uncertainty* raised with respect to the third technical assessment factor, and that single factor is graded as ◑ *might raise nonproliferation concerns.* However, it should be pointed out that this issue is unavoidable (unless the United States elects to neither produce

Table ES-4. Assessments of Alternatives and Options as Defined in the Draft NI PEIS

		Technical Factors			*Policy Factors*			
Alternatives	***Options***	Assuring Against Theft or Diversion	Facilitating Cost-Effective International Monitoring	Resulting in Final Material Forms from which Retrieval is More Difficult than from Original Material Forms	Maintaining Consistency with U.S. Nonproliferation Policy	Avoiding Encouragement of Plutonium Reprocessing	Building Confidence that the U.S. (Russia)* is not Producing Material for Nuclear Weapons	Supporting Negotiation of a Verifiable FMCT
No Action Alternative*	1	◑	◑	○	●	●	●	◑
	2	◑	◑	○	●	●	●	◑
	3	◑	◑	○	●	●	●	◑
	4	◑	◑	○	●	●	●	◑
Alternative 1: *Restart FFTF*	1	●	●	◑	●	●	●	●
	2	●	○	◑	●	◑	◑	○
	3	●	●	◑	●	●	●	●
	4	●	●	◑	●	●	●	●
	5	●	○	◑	●	◑	◑	○
	6	●	●	◑	●	●	●	●
Alternative 2: *Use Only Existing Operational Facilities*	1	●	●	◑	●	●	●	●
	2	●	○	◑	●	◑	◑	○
	3	●	●	◑	●	●	●	●
	4	●	●	◑	●	●	●	●
	5	●	○	◑	●	◑	◑	○
	6	●	●	◑	●	●	●	●
	7	●	●	◑	●	●	●	●
	8	●	○	◑	●	◑	◑	○
	9	●	●	◑	●	●	●	●
Alternative 3: *Construct New Accelerator(s)*	1	●	●	◑	●	●	●	●
	2	●	○	◑	●	◑	◑	○
	3	●	●	◑	●	●	●	●
Alternative 4: *Construct New Research Reactor*	1	●	●	◑	●	●	●	●
	2	●	○	◑	●	◑	◑	○
	3	●	●	◑	●	●	●	●
Alternative 5: *Permanently Deactivate FFTF (with no new missions)**	-	◑	◑	○	●	●	●	◑

* Under the No Action Alternative (Options 1-4) and Alternative 5, the Russian Pu-238 purchase option is considered.

● *Fully meets nonproliferation objectives*
◑ *Might raise nonproliferation concerns*
○ *Raises nonproliferation concerns*

nor purchase Pu-238) and impacts all alternatives and options, including the No Action Alternative and Alternative 5: permanently deactivate FFTF with no new missions at U.S. facilities.

Civil Nuclear Energy Research and Development. The DOE Office of Nuclear Energy has included Accelerator Transmutation of Waste (ATW) as one of many possible future civil nuclear energy R&D missions as a placeholder in the event that the U.S. Government decides to pursue this technology. Currently, the Department is performing technical paper studies and planning studies (*e.g.*, the "ATW Road Map") to assist Congress with fiscal and program planning. These efforts are also being reviewed by the independent Nuclear Energy Advisory Committee (NERAC) Subcommittee on the Accelerator Transmutation of Waste, which, in its report of May 23, 2000, recommended that, a study should be launched to identify potential proliferation concerns associated with ATW and possible approaches to mitigate identified concerns. A comprehensive nonproliferation impact assessment of the ATW program plan will be performed by the Office of Arms Control and Nonproliferation prior to proceeding beyond paper studies with actual fuels materials testing in support of ATW (or other technologies that include or imply closed fuel cycle technologies). As such, the nonproliferation impact of a possible future ATW program is not considered in this NI NIA since it is not a well-defined, principal identified mission at this time. It will, however, be considered in a future nonproliferation impact assessment if the ATW Program moves forward. With respect to other identified civil nuclear energy R&D missions, there *are no significant identified concerns* demonstrating how, within the bounds of the description given in the Draft NI PEIS, the pursuit of these missions is contrary to U.S. nonproliferation objectives as defined by any assessment factor. In fact, the development of proliferation resistant nuclear fuels and technologies are a significant feature of the intended R&D program. Therefore, this mission is graded as ● *fully meets nonproliferation objectives.*

ES-7.2 NONPROLIFERATION MOST AND LEAST FAVORABLE ALTERNATIVES AND OPTIONS

Since the assessments of alternatives and options are largely determined by the Pu-238 processing facility assessments, the options that use the REDC and FMEF have the most favorable assessments, and the options that use the FDPF have the least favorable assessments. The No Action Alternative and Alternative 5 use the Russian Pu-238 purchase option. These alternatives score between most and least favorable. As a result, the *most favorable nonproliferation alternatives and options* are:

- Alternative 1: Restart FFTF, Options 1, 3, 4, and 6
- Alternative 2: Use Only Existing Facilities, Options 1, 3, 4, 6, 7, and 9
- Alternative 3: Construct New Accelerator(s), Options 1 and 3
- Alternative 4: Construct New Research Reactor, Options 1 and 3

The *least favorable nonproliferation alternatives and options* are:

- Alternative 1: Restart FFTF, Options 2 and 5
- Alternative 2: Use Only Existing Facilities, Options 2, 5, and 8
- Alternative 3: Construct New Accelerator(s), Option 2
- Alternative 4: Construct New Research Reactor, Option 2

ES-7.3 SPECIAL CONSIDERATIONS FOR ALTERNATIVE 1: RESTART FFTF

If the Nuclear Infrastructure Record of Decision elects to restart FFTF (under any option), there are some special considerations. To codify the assumptions underlying the conclusion that restart of the FFTF fully meets U.S. nonproliferation policy objectives, the Nuclear Infrastructure Record of Decision should include the following commitments:

- The FFTF will not be configured to operate as a breeder reactor (breeding ratio equal to or greater than one) or to optimize the production of plutonium.
- Spent MOX fuel irradiated in the FFTF will not be reprocessed.
- During the period that the FFTF is fueled with Hanford MOX fuel, an analysis will be undertaken by the RERTR program to determine whether the reactor can be fueled with LEU fuel, and if this is shown to be technically feasible, the reactor will be fueled with LEU fuel following the consumption of existing MOX fuel (Hanford and, possibly, German MOX fuel).
- A nonproliferation impact assessment will be prepared on the ATW program prior to the test irradiation of ATW fuels materials in the FFTF.
- The FFTF will remain available for international monitoring.

ES-7.4 NONPROLIFERATION UNCERTAINTIES, CONCERNS, AND MITIGATION APPROACH

There are a limited number of nonproliferation concerns and uncertainties that might be mitigated to increase the number of alternatives and options that have optimum nonproliferation qualities for the missions described in the Draft NI PEIS. These concerns are associated with the U.S. and Russian facilities used to process and recover Pu-238.

- If managed access can be granted to the FDPF, sufficient for verification of an FMCT, the uncertainties and concerns associated with the use of FDPF for the Pu-238 processing mission would be effectively mitigated (with the exception of the material forms technical factor).
- If the United States had sufficient confidence concerning the rigor of Russian controls on ANM, this uncertainty would be effectively mitigated.
- If Russia were to implement a moratorium on spent nuclear fuel reprocessing, the material forms technical factor would be partially mitigated to "◑ might raise nonproliferation concerns" – similar to the U.S. Pu-238 program assessments, since Russia would no longer be able to add to its stocks of separated neptunium.
- If managed access can be granted to the Russian facility responsible for Pu-238 and neptunium recovery, sufficient for verification of an FMCT, the uncertainties associated with the use of a Russian facility for the Pu-238 processing mission would be effectively mitigated (with the exception of the material forms technical factor).

1 INTRODUCTION

1.1 PURPOSE

This document assesses the potential nonproliferation impacts that might result from U.S. Department of Energy (hereafter referred to as the Department or DOE) nuclear infrastructure improvements as proposed and described in the *Draft Programmatic Environmental Impact Statement for Accomplishing Expanded Civilian Nuclear Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility* (DOE/EIS 0310D), July, 2000 (hereafter referred to as the Draft NI PEIS). The DOE Office of Arms Control and Nonproliferation has prepared this *Nuclear Infrastructure Nonproliferation Impact Assessment for Accomplishing Expanded Civilian Nuclear Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility* (hereafter referred to as the NI NIA). Together with the Draft NI PEIS and an associated cost report, both being prepared by the DOE Office of Nuclear Energy, this assessment is being made available to the public as part of the Department's decision-making process to evaluate nuclear infrastructure improvement alternatives.

The United States has an annual requirement for the production of radioisotopes needed for medical, industrial, and scientific applications. The Department has an obligation to supply Pu-238 thermal/power supplies to support currently scheduled and future NASA missions. Civil nuclear energy research and development (R&D) is also required to support future U.S. nuclear energy production, civil nuclear waste disposal, and possible nuclear science applications (*e.g.,* space reactors for future NASA missions). These programmatic needs, particularly those emanating from the projected growth rate in the use of medical isotopes and the continued requirement to produce isotopes for other applications (*e.g.,* Pu-238 for NASA missions), have led the Department to consider various infrastructure improvement alternatives, including the utilization of existing and new facilities.

The Department issued a Notice of Intent on September 15, 1999 to prepare a PEIS for specified alternatives to accomplish these nuclear infrastructure missions.[1] The Notice of Intent identified alternatives as follows: 1) resume Fast Flux Test Facility (FFTF) operation; 2) construct and operate a new research reactor at a generic DOE site; 3) construct and operate one or more new neutron-producing accelerators at a generic DOE site; or 4) meet these projected mission needs utilizing existing reactor and accelerator facilities (other than FFTF). The Draft NI PEIS assesses the environmental impact of all these alternatives, though not in precisely this order. Furthermore, the Draft NI PEIS also evaluates a No Action Alternative and a fifth alternative (permanently deactivate FFTF with no new missions at any U.S. facilities). This NI NIA will follow the same delineation of alternatives as the Draft NI PEIS to assess the nonproliferation impact of actions that are proposed in the Draft NI PEIS.

1.2 STRUCTURE

This NI NIA is divided into ten Sections:

Section 1 presents introductory material to orient the reader to the structure, purpose, objective, and scope of the NI NIA. Furthermore, the missions, facilities, alternatives and options, and relevant nuclear materials identified and defined in the Draft NI PEIS and under evaluation in this assessment, are presented.

[1] "Notice of Intent To Prepare a Programmatic Environmental Impact Statement for Accomplishing Expanded Civilian Nuclear Energy Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility," 64 *Fed. Reg.* 50064, 1999.

Section 2 provides U.S. nonproliferation policy background and context to frame the detailed technical and policy analysis presented in NI NIA. This "big-picture" view is essential to understanding the importance of the U.S. Government's nonproliferation agenda and the objectives at issue in this NI NIA to the Department's decision making process.

Section 3 defines technical and policy evaluation factors that are the basis of the nonproliferation analysis along with the qualitative grading scale. Furthermore, the method used to evaluate the nonproliferation merits and drawbacks of the Draft NI PEIS facilities, alternatives and options is described.

Section 4 presents a comprehensive nonproliferation assessment of the proposed restart of the FFTF. The majority of nonproliferation concerns expressed by non-government organizations (NGOs) and citizens during the public scoping period for the NI PEIS, were focussed on Alternative 1 – Restart FFTF. Furthermore, although many facilities are identified in the Draft NI PEIS, only the FFTF is mentioned in the formal title of the document. In response to these indications of the prominent nature of the FFTF in the Draft NI PEIS, this NI NIA devotes an entire section to a comprehensive nonproliferation analysis of that irradiation facility.

Section 5 presents nonproliferation assessments of other irradiation facilities proposed under alternatives presented in the Draft NI PEIS: the Advanced Test Reactor (ATR), the High Flux Isotope Reactor (HFIR), a generic commercial light water reactor (CLWR), and three proposed new DOE irradiation facilities, including a new high-energy accelerator, a new low-energy accelerator, and a new research reactor.

Section 6 presents nonproliferation assessments of target fabrication and processing facilities proposed under the alternatives presented in the Draft NI PEIS: the Radiochemical Engineering Development Center (REDC), the Fluorinel Dissolution Process Facility (FDPF), the Fuels and Materials Examination Facility (FMEF), the Radiochemical Processing Laboratory (RPL) and Hanford Building 306-E (306-E), and a proposed new DOE target fabrication and processing facility referred to as the new support facility.

Section 7 presents a summary showing all the facility nonproliferation assessment grades in a single table. Furthermore, mitigation approaches to improve facility assessments are presented.

Section 8 presents nonproliferation assessments of the Draft NI PEIS Alternatives and Options. "Weak link" analysis is performed using the facility nonproliferation assessments to roll them into cumulative evaluations of the 26 different alternatives and options under consideration in the Draft NI PEIS. In order to perform the alternative and options assessments, continued U.S. purchases by the Department of Russian Pu-238 is assessed, as is the nuclear material transportation required to implement various alternatives and options.

Section 9 presents conclusions and recommendations based upon the nonproliferation assessments provided in Sections 4 through 8. The nonproliferation merits and drawbacks of the Draft NI PEIS missions, independent of selected facilities, are assessed from an overall point of view. The conclusions identify the alternatives and options with the most and least favorable nonproliferation scores and, based upon those conclusions, makes recommendations. Mitigating actions that might be taken to improve the nonproliferation assessments are summarized.

Section 10 presents supporting appendix material including: additional nonproliferation concepts, definitions, and background; the complete text of two immediately relevant policy and legal documents; a preliminary technical assessment of FFTF operational characteristics relevant to this NI NIA; and a list of acronyms.

Additional Comments on Assessment Structure. This is a comprehensive nonproliferation technical policy assessment of a complex subject document: the Draft NI PEIS. To the greatest extent possible, the structure of this assessment is organized to improve reader comprehension of the myriad issues discussed. As a technical document, technical acronyms are used to reduce the wordiness of technical discussions with repetitive technical terms. To assist the lay reader, each new section redefines each acronym used in its first use in that section. Furthermore, a list of acronyms used in this assessment is included in Appendix 10.5. The common abbreviation is also used to indicate isotopes, such as Pu-238, to indicate the plutonium isotope having 238 nucleons in its nucleus. Measurement units are presented similarly to acronyms in that they are defined on first use in a given section. Metric measurement units are used most often except for lengths that are occasionally expressed in English units to indicate distances between facilities (miles) or dimensions of buildings (feet). Footnotes are used extensively to provide references for information and to allow for further discussion for interested readers without burdening the assessment text with excessive digressions.

1.3 OBJECTIVE AND SCOPE

The objective of the NI NIA is to evaluate the relationship between the missions, facilities, alternatives, and options as described in the Draft NI PEIS, and the body of U.S. Government nonproliferation policy, U.S. laws and regulations, and international agreements. Based on that evaluation, the NI NIA presents conclusions and recommendations regarding the nonproliferation merits and drawbacks of the various activities proposed in the Draft NI PEIS to assist the Secretary of Energy to render a Record of Decision following publication of the Final NI PEIS.

This assessment is limited to an evaluation of the direct and reasonably implied nonproliferation impact of the activities proposed in the Draft NI PEIS. Mission necessity, safety, environmental impact, effectiveness, costs, and life-cycle economics of activities described in the Draft NI PEIS are not considered to be central to the nonproliferation analysis reported in the NI NIA. As such, these issues are not presented in detail in the NI NIA. However, technical discussions that explain the purpose, intent, history or typical operations of certain nuclear technologies are presented to improve the reader's understanding of the nonproliferation analysis.

1.4 MISSIONS AS DESCRIBED IN THE DRAFT NI PEIS

1.4.1 Medical, Industrial and Research Isotope Production

The United States has an annual requirement for production of radioisotopes needed for medical, industrial and scientific applications. In particular, an Expert Panel recently convened by DOE concluded the growth rate in medical isotope use will be significant over the next 20 years, ranging from 7 to 14% per year for therapeutic applications, and from 7 to 16% per year for diagnostic applications. The panel noted that these growth rates are attainable only if basic research in nuclear medicine is supported and if modern, reliable isotope production facilities are available. To meet current and future medical needs, the Expert Panel recommended that:

> …the United States develop a capability to produce large quantities of radionuclides [radioisotopes] to maintain existing technologies and to stimulate future growth in the biomedical sciences. The successful implementation of such a program would help insure our position as an international leader in the biomedical sciences well into the twenty-first century. The panel recommends that the U.S. government build this capability around a reactor, an accelerator, or a

combination of both technologies as long as isotopes for clinical and research applications can be supplied reliably, with diversity in adequate quantity and quality.[2]

Industrial and research isotope applications fall into three broad categories: nucleonic instrumentation, irradiation and radiation processing, and non-medical technologies that utilize radioactive tracers. Examples of nucleonic instrumentation include detection systems for pollutants, explosives, drugs, and household smoke detectors. Examples of irradiation and radiation processing include bio-sterilization of certain food products (spices and pork are often irradiated among other food products) and medical products and industrial plastic curing processes. Examples of radioactive tracer applications would be transport/uptake analysis of nutrients, fertilizers, herbicides and other pollutants in plants, soils, and groundwater as well as laboratory-based studies of material properties.

1.4.2 Plutonium-238 Production

DOE and its predecessor agencies have been developing and supplying radioisotope power systems and heater units to NASA for space exploration for more than 30 years. Previous NASA space missions that have used radioisotope power systems include the Apollo lunar scientific packages and the Pioneer, Viking, Voyager, Galileo, and Ulysses missions. More recent missions include the Mars Pathfinder mission launched in 1996 and the Cassini mission launched in 1997. The radioisotope used in these systems is Pu-238. These systems have repeatedly demonstrated their performance, safety, and reliability in various NASA missions. Through a Memorandum of Understanding with NASA, DOE has agreed that it will provide the Pu-238 necessary for space missions that require or are enhanced by nuclear power systems and heater units. In addition, under the National Space Policy issued by the Office of Science and Technology Policy in September 1996, and consistent with Department’s charter under the Atomic Energy Act, DOE is responsible for maintaining the capability to provide the Pu-238 needed to support these missions.

The Intersector Guidelines section of the National Space Policy States that "The Department of Energy will maintain the necessary capability to support space missions, which may require the use of space nuclear power systems." Currently, there is no suitable alternative to using Pu-238 to support these space missions.

Historically, the reactors and chemical processing facilities at the Department’s Savannah River Site (SRS) were used to produce Pu-238. However, downsizing of the DOE nuclear weapons complex resulted in the shutdown of these reactors in the late 1980s. The SRS radiochemical processing facilities are also planned for shutdown following processing of certain irradiated materials that pose a health and safety risk and the demonstration of new non-chemical processing disposal technology to treat other materials at SRS that require disposition.

Because the supply of Pu-238 produced at SRS to support NASA space missions is limited, DOE signed a 5-year contract in 1992 to purchase Pu-238 from Russia, authorizing the United States to purchase up to 40 kilograms (kg) of Pu-238 with an annual maximum purchase of 10 kg. Under this contract, DOE purchased 9 kg of Pu-238. In 1997, DOE extended the contract for another 5 years. This purchase option will remain viable until 2002. However, the longer-term viability of this option is unclear, and the current inventory will be depleted by the middle of this decade. In 2000, NASA provided preliminary guidance to DOE to plan for providing the necessary radioisotope power systems to support the Pluto/Kuiper Express

[2] Wagner, et. al., 1998, Expert Panel: Forecast Future Demand for Medical Isotopes, Medical University of South Carolina, presented in Arlington, VA, September 25-26.

mission in 2004, the Europa Orbiter mission in 2006, and the Solar Probe mission in 2007. DOE would also provide radioisotope heater units for these missions and several NASA Mars Surveyor missions.

The political and economic climate in Russia creates uncertainties that could affect its reliability as a source of Pu-238 to satisfy future NASA space mission requirements. Moreover, information is limited concerning the extent of the Russian supply, Russian plans on how they would satisfy future demand, and the nuclear safety and domestic safeguards of Russian production facilities. The Draft NI PEIS concluded that it is not in the best interest of the United States to continue relying on foreign sources to provide an assured, uninterrupted supply of Pu-238 to satisfy future U.S. space mission requirements. Accordingly, DOE proposes to re-establish a domestic capability for producing and processing this material. Since the SRS facilities previously used for Pu-238 production are no longer available, DOE needs to evaluate other DOE irradiation and chemical processing facilities, as well as potential CLWRs, for this mission. Unless an assured domestic supply of Pu-238 is established, the Draft NI PEIS concluded that the Department's ability to support future space missions may be lost.

1.4.3 Civil Nuclear Energy Research and Development

Civil nuclear power plants supply 17% of the world's electricity. Of the total electricity consumed in the United States in 1999, nuclear power supplied 20%. Furthermore, nuclear power plants have supplied electricity safely and have reduced greenhouse gas emissions that are generated when electricity is produced using fossil fuels (coal, oil and natural gas). In the future, re-licensed CLWRs and possibly advanced nuclear reactors and fuel cycle technologies will provide clean, safe, and increasingly proliferation resistant nuclear generated electricity to help meet the Nation's expanding electricity requirements, while helping to meet rising international controls and agreements on greenhouse gas emissions. An enhanced DOE nuclear facility infrastructure includes three broad mission areas: materials research, nuclear fuel research, and advanced reactor development.

Materials Research. The high radiation fields, high temperatures, and corrosive environments in nuclear reactors (terrestrial or space) or other complex nuclear systems (*e.g.*, accelerator transmutation of waste [ATW]) can accelerate the degradation of reactor pressure vessels and structural material, component materials, material interfaces, and joints between materials (*e.g.*, welds). Radiation effects in materials can cause a loss of mechanical integrity (fracture toughness and ductility) by embrittlement, dimensional changes (creep and swelling), and fatigue and cracking (irradiation-assisted stress corrosion cracking). Acquiring a fundamental understanding of radiation effects in current and future reactor materials (engineered steel alloys, ceramics, composites, and refractory metals), as well as the experimental validation of analytical models and computational methods, will require material irradiation testing over a range of neutron energies (thermal and fast flux) and doses. Material testing under simulated reactor conditions will be required to ensure the compatibility of advanced materials with the various moderators/coolants of future reactor concepts. In addition, the thermophysical properties and behaviors of liquid metal coolants being considered for advanced reactor (terrestrial or space) and ATW systems require further irradiation testing. One key area of materials research that is important to plant safety and the license renewal of existing nuclear power plants is the accelerated aging of materials to simulate radiation effects over a plant lifetime. Researchers from the United States and many foreign countries use the Department's high flux research reactors for materials testing and experimentation. These facilities have the capability to maintain a high density of neutrons in a given test volume for materials testing, to shorten the time needed for such testing, to tailor the neutron flux to simulate the different reactor types and conditions, and have instrumented cores for close monitoring of the test conditions.

Nuclear Fuel Research. Increasing demands are being placed on nuclear fuel and cladding material performance as the fuel burnup limits are extended in existing CLWRs to maximize plant performance and economic benefits. New fuel types are being investigated that offer potential benefits such as enhanced proliferation resistance (uranium-thorium fuel), higher burnup, and improved waste forms for the new reactor concepts being researched and developed by DOE. In addition, plutonium-uranium mixed oxide fuels are being developed for the disposition of excess nuclear weapons plutonium, and high temperature, long-life fuels may be required for space reactors. Each of the various fuel and cladding types and material compositions will require research and irradiation testing under prototypical reactor conditions to fully understand fuel performance, cladding performance, cladding/fuel interaction, and cladding/coolant material compatibility. Fuel research includes a variety of thermal and fast spectrum power reactor fuel forms (ceramic, metal, hybrids such as cermet) and various fuel types (oxides, nitrides, carbides, and metallics). Irradiation experiments to characterize fuel performance will require the capability to test fuel pellets, pins, and fuel assemblies under steady-state and transient conditions in the various higher temperature environments expected in future reactor designs. Irradiation experiments are also necessary to obtain criticality safety and reactor physics data for benchmarking the computational codes and analytical methods used in fuel design and performance analysis.

Advanced Reactor Development. Certification and licensing of advanced reactor and complex nuclear systems, such as ATW, will require the demonstration and validation of reactor and safety system thermal and fluid dynamic properties under steady-state and transient conditions. Typically non-nuclear test loops are used to perform this research. However, because of the unique nature of some proposed advanced reactor concepts, test loop operation under prototypical temperature and neutron flux conditions will be necessary to adequately test and demonstrate coolant/moderator physics and thermal properties, heat transfer, fluid flow, and fuel-moderator performance.

1.5 FACILITIES, ALTERNATIVES, AND OPTIONS

The facilities identified by the Department in the Draft NI PEIS are presented in Table 1-1. The irradiation facilities are described and evaluated in Sections 4 and 5 and target fabrication and processing facilities are described and evaluated in Section 6. The facility type, name, location, acronym assigned in the NI NIA, and the operational status of each facility is shown in the table.

Using the facilities identified above, the Department has defined five potential alternatives and a No-Action Alternative to accomplish the missions described in Section 1.4. Table 1-2 defines the five alternatives and enumerates the options under each alternative (*i.e.*, the facility variations within each alternative). Each alternative and option will be evaluated in Section 8. Under the No Action Alternative (all options) and Alternative 5, Pu-238 is purchased from Russia to meet NASA program requirements. Under the No Action Alternative, Option 1, and Alternative 5, the neptunium inventory remains at SRS and its interim disposition is covered under a previous National Environmental Protection Act (NEPA) action that is not evaluated in this assessment, but oxidation processing required at SRS to stabilize neptunium nitrate solutions for transportation or storage is considered as a special case in Section 6.[3] The production of radioisotope power and heating units by Los Alamos National Laboratory (using Pu-238) for use by NASA programs is considered as a special case in Section 6. Furthermore, under all options in Alternatives 2, 3, 4 and 5, FFTF is permanently deactivated. FFTF standby/deactivation is covered by a previous NEPA action that is not evaluated in this assessment, but the standby/deactivation activity is covered as a special case under the comprehensive FFTF nonproliferation assessment given in Section 4.[4]

[3] *Final Environmental Impact Statement, Interim Management of Nuclear Materials at the Savannah River Site,* DOE/EIS-0220, October, 1995.
[4] *Environmental Assessment – Shutdown of the Fast Flux Test Facility, Hanford Site, Richland, Washington,* DOE/EIA-0993, May, 1995.

Table 1-1. Facilities Identified in the Draft NI PEIS

Type	Name	Acronym	Location	Status
Irradiation	Fast Flux Test Facility	FFTF	Hanford, WA	Standby
	Advanced Test Reactor	ATR	Idaho National Energy and Environmental Laboratory (INEEL), ID	Operational
	High Flux Isotope Reactor	HFIR	Oak Ridge National Laboratory (ORNL), TN	Operational
	Commercial Light Water Reactor	CLWR	Existing CLWR site to be determined	Operational
	New High-Energy Accelerator New Low-Energy Accelerator	- -	Existing DOE site to be determined	- -
	New Research Reactor	-	Existing DOE site to be determined	-
Target Fabrication and Processing	Radiochemical Engineering Development Center	REDC	Oak Ridge National Laboratory (ORNL), TN	Operational
	Fluorinel Dissolution Process Facility CPP-651	FDPF CPP-651	Idaho National Energy and Environmental Laboratory (INEEL), ID	FDPF: Non-operational Available CPP-651: Operational
	Fuels and Materials Examination Facility	FMEF	Hanford, WA	Non-operational Available
	Radiochemical Processing Laboratory Building 306-E	RPL 306-E	Hanford, WA	Operational
	New Support Facility	-	Existing DOE site to be determined	-

1.6 NUCLEAR MATERIALS RELEVANT TO THIS ASSESSMENT

1.6.1 Designations for Nuclear Materials

Special Nuclear Material (SNM) is a U.S. statutory designation used by the DOE and the Nuclear Regulatory Commission (NRC) to indicate materials bearing: uranium enriched above natural in the isotope U-235, U-233, and several isotopes of plutonium (Pu-238, 239, 240, 241, 242). The designation SNM captures material containing stable fissile isotopes of uranium and plutonium.[5]

Special Fissionable Material (SFM) is an international statutory designation used by the IAEA to indicate materials bearing: uranium enriched above natural in the isotope U-235, U-233, and Pu-239. The designation SFM captures weapons-usable uranium and mixtures of plutonium isotopes through capture of Pu-239. Although the IAEA Statue definition typically captures isotopically concentrated Pu-238 as SFM (because it contains Pu-239), it is exempted from international safeguards, in paragraph 36 of *IAEA INFCIRC/153 (Corrected), 1972,* if the plutonium is more than 80% Pu-238.

Alternate Nuclear Material (ANM) is a recent designation for neptunium and isotopes of americium. The designation ANM captures weapons-usable materials that are not legally recognized as SNM or SFM. The legal distinction is maintained for practical reasons that are explained in Section 2.1.8.

Source Material (SM) is a universal statutory designation to indicate materials bearing: uranium that is depleted in the isotope U-235 or at the natural isotopic ratio, and thorium. The designation SM captures materials from which fissile materials may be derived.

[5] The Department designates materials bearing plutonium that is greater than 60% Pu-238 to be Attractiveness E (All Other Materials).

Table 1-2. Alternatives and Options Defined in the Draft NI PEIS

Alternatives	Options	Irradiation Facility	Pu-238 Production Mission		Medical and Industrial Isotope Production and Nuclear Energy Research and Development Mission	
			Storage Facility	*Processing Facility*	*Storage Facility*	*Processing Facility*
No Action Alternative[d, e]	1	-	-	-	-	-
	2	-	REDC	-	-	-
	3	-	CPP-651	-	-	-
	4	-	FMEF	-	-	-
Alternative 1: *Restart FFTF*[g]	1	FFTF[a]	REDC	REDC	RPL/306-E	RPL/306-E
	2	FFTF[a]	FDPF/CPP-651	FDPF	RPL/306-E	RPL/306-E
	3	FFTF[a]	FMEF	FMEF	FMEF	FMEF
	4	FFTF[b]	REDC	REDC	RPL/306-E	RPL/306-E
	5	FFTF[b]	FDPF/CPP-651	FDPF	RPL/306-E	RPL/306-E
	6	FFTF[b]	FMEF	FMEF	FMEF	FMEF
Alternative 2: *Use Only Existing Operational Facilities*[f]	1	ATR	REDC	REDC	-	-
	2	ATR	FDPF/CPP-651	FDPF	-	-
	3	ATR	FMEF	FMEF	-	-
	4	CLWR	REDC	REDC	-	-
	5	CLWR	FDPF/CPP-651	FDPF	-	-
	6	CLWR	FMEF	FMEF	-	-
	7	HFIR/ATR	REDC	REDC	-	-
	8	HFIR/ATR	FDPF/CPP-651	FDPF	-	-
	9	HFIR/ATR	FMEF	FMEF	-	-
Alternative 3: *Construct New Accelerators*[f, g, h]	1	New	REDC	REDC	New[c]	New[c]
	2	New	FDPF/CPP-651	FDPF	New[c]	New[c]
	3	New	FMEF	FMEF	New[c]	New[c]
Alternative 4: *Construct New Research Reactor*[f]	1	New	REDC	REDC	New[c]	New[c]
	2	New	FDPF/CPP-651	FDPF	New[c]	New[c]
	3	New	FMEF	FMEF	New[c]	New[c]
Alternative 5: *Permanently Deactivate FFTF (with no new missions)*[d]	-	-	-	-	-	-

a) FFTF operates with MOX fuel for 21 years and uranium fuel for 14 years.
b) FFTF operates with MOX fuel for 6 years and uranium fuel for 29 years.
c) The New Support Facility would not be required if a DOE site with available support capability and infrastructure is selected.
d) Under the No Action Alternative (all options) and Alternative 5, Pu-238 is purchased from Russia to supply NASA programs.
e) Under the No Action Alternative, FFTF is maintained in standby mode indefinitely.
f) Under Alternatives 2, 3, and 4, the FFTF is permanently deactivated.
g) The ATW placeholder is not evaluated in this NI NIA. The ATW program will be the topic of a future ATW NIA.
h) A new low-energy accelerator might also be combined with reactor options under Alternative 2 to fulfill all proposed missions.

1.6.2 Mixed Oxide Reactor Fuel

Fresh and spent MOX fuel contains plutonium isotopes that are immediately useful as a fissile material in nuclear weapons following chemical separation from the uranium contained in the fuel matrix and metallurgical processing. MOX fuel (PuO_2 mixed with UO_2 in sintered pellet form) is intended as the initial fuel supply for the Fast Flux Test Facility (FFTF) in the event that a Record of Decision directs FFTF to restart. FFTF uses fresh MOX fuel that has between 23 and 29% (by oxide mass) plutonium oxide in the fresh oxide fuel material. Higher or lower plutonium concentrations might also be used. Two sources of fresh MOX fuel for FFTF have been identified in the Draft NI PEIS:

- FFTF MOX fuel currently stored at the Hanford site that was remaining when FFTF went into standby mode. There is enough Hanford MOX fuel to operate the reactor at 100 megawatts thermal (MWt) for about 6 years. This fuel is hereafter referred to as Hanford MOX fuel.
- Partially remanufactured German SNR-300 MOX fuel currently stored at Hanau, Germany and Dounreay, Scotland. This fuel would require some remanufacturing and would be imported to the United States for use in the FFTF. There is enough German SNR-300 MOX fuel to operate the FFTF at 100 MWt for about 15 years following the consumption of the Hanford MOX fuel. This fuel is hereafter referred to as German MOX fuel.

1.6.3 Highly Enriched Uranium Reactor Fuel

All uranium enriched in U-235 to or above 20% is called highly enriched uranium (HEU). HEU fuel is required to operate two of the irradiation facilities proposed in the Draft NI PEIS: the High-Flux Isotope Reactor (HFIR) and the Advanced Test Reactor (ATR). Both research reactors use aluminum clad HEU oxide plate fuel. The HEU contained in the HFIR and ATR plate fuel is 93% enriched such that it is immediately useful as a fissile material in nuclear weapons following chemical separation from the fuel matrix and metallurgical processing.

HEU fuel may be required to operate FFTF following the consumption of available MOX fuel supplies. FFTF can use HEU oxide fuel in the form of sintered pellets. The HEU contained in the FFTF oxide fuel is enriched to between 30 and 37%. International and domestic safeguards regulations treat uranium, that is enriched above 20%, as material that is usable as fissile material for nuclear weapons. However, higher assays are more readily usable than lower assays.

1.6.4 Low Enriched Uranium Reactor Fuel

Any uranium enriched in U-235 to less than 20% is called low enriched uranium (LEU). LEU fuel is required to operate two of the irradiation facilities proposed in the Draft NI PEIS: commercial light water reactor (CLWR) and new research reactor. A CLWR uses sintered LEU oxide fuel pellets enriched to between 3 and 4%. A new research reactor would use aluminum clad LEU oxide plate fuel enriched to slightly below 20%. In both cases, conversion to uranium hexafluoride, further enrichment and metallurgical processing would be required to obtain material that is readily usable for nuclear weapons.

In fiscal year 2001, the Department’s RERTR program plans to study conversion of ATR to use LEU fuel. If a Record of Decision directs a restart of FFTF, the RERTR program will study the conversion of FFTF to LEU fuel. In both cases, If LEU fuel is found to be technically feasible, it would probably be enriched to slightly less than 20%. LEU fuel would require conversion to uranium hexafluoride, further enrichment and metallurgical processing to obtain material that is readily usable for nuclear weapons.

1.6.5 Neptunium

The Pu-238 production mission described in the Draft NI PEIS requires the production and irradiation of neptunium targets. Neptunium targets are typically made of purified, concentrated neptunium dioxide with an aluminum binder, canned or clad in aluminum. The production of Pu-238 requires:

- The production of purified neptunium dioxide from neptunium solution followed by target fabrication;
- Irradiation to build in Pu-238 via neutron capture and beta decay, solvent extraction and ion exchange processing to separate and purify neptunium and Pu-238 from fission products and other waste products; and
- A repeat of the cycle to produce further Pu-238.

Each cycle reduces the inventory of neptunium available for Pu-238 production since neptunium is converted to Pu-238 in the process. During the production cycle, neptunium is in different solid (*e.g.*, oxide powders and pressed solid matricies) and liquid forms (*e.g.*, nitrate solutions).

Neptunium is ANM. The utility of ANM in nuclear weapons is recognized by the U.S. Government and the international community. For the purposes of DOE safeguards, ANM is treated as equivalent to U-235. As such, it is subject to DOE safeguards that are similar to those for very highly enriched uranium and is reportable in gram quantities.[6]

1.6.6 Plutonium-238

The production of Pu-238 requires the production of purified neptunium dioxide from neptunium solution followed by target fabrication, irradiation to build in Pu-238 via neutron capture and beta decay, solvent extraction and ion exchange processing to separate and purify neptunium and Pu-238 from fission products and other waste products, and a repeat of the cycle to produce further Pu-238. During the production cycle, Pu-238 is in different solid (*e.g.*, oxide powders and pressed solid matricies) and liquid forms (*e.g.*, nitrate solutions). During the process of building Pu-238 into neptunium targets, a small amount of Pu-239 is also produced by second neutron captures by Pu-238. Since the desired product is relatively pure Pu-238, the secondary production of Pu-239 is intentionally limited. This limits the build in of Pu-238 to about 10% to 15% of the neptunium content of the fresh target.

Pu-238 is SNM. However, isotopically concentrated Pu-238 (above 80%) is generally recognized to not constitute a nuclear proliferation threat. The IAEA exempts plutonium that contains more than 80% Pu-238 from international safeguards. However, this material is rigorously protected against loss, theft and sabotage (through physical protection and accounting) and is strictly contained (to prevent accidental release) as a result of the health and safety risks presented by the material. Under DOE safeguards, Pu-238 is reportable in 0.1 gram quantities.

1.6.7 Target and Product Materials Associated with Isotope Production Missions

A wide variety of materials (radioactive and nonradioactive) are described in the Draft NI PEIS to produce targets for the production of medical and industrial isotopes. None of the materials listed as targets or products are materials of nuclear nonproliferation concern. As such, these materials are not relevant to this NI NIA.

1.6.8 Civil Nuclear Energy Research and Development Materials

The nuclear materials that might be involved in civil nuclear energy R&D are not described, or listed in detail in the Draft NI PEIS. However, example missions are described. This NI NIA focuses on the use of materials of nuclear nonproliferation concern (plutonium, HEU, and neptunium) in facilities, alternatives,

[6] See Section 2.1.8

and options described in the Draft NI PEIS. Nuclear R&D studies on materials other than the listed materials of concern are not germane to this NI NIA.

Some of the described missions involve nuclear fuel materials in the form of proliferation resistant reactor fuels and fuels designed to convert long-lived nuclear waste isotopes into short-lived fission products. Other missions typically involve high flux irradiation testing on non-nuclear materials associated with various civil nuclear energy missions. Irradiation testing on non-nuclear materials is not relevant to this NI NIA.

Fuels testing may include nuclear materials such as "proliferation resistant" uranium-thorium fuel and non-fertile transuranic (TRU) fuels. Furthermore, MOX fuels associated with excess defense Pu-disposition may also be irradiation tested.

The production of non-fertile TRU fuels (*e.g.*, for Accelerator Transmutation of Waste [ATW]), if pursued in a future R&D program, would warrant evaluation in a nonproliferation impact assessment. These fuels are described in the Draft NI PEIS as:

> …a composition of 75 percent zirconium and 25 percent transuranic elements, by weight. The transuranic elements would likely be light water reactor discharge fuel at a typical burnup of 33,000 megawatt-days per metric ton of uranium that is stripped of essentially all uranium and fission products. Comparisons of this fuel to the standard FFTF fuel indicate comparable plutonium compositions.[7]

The term "transuranic" refers to the actinides present in nuclear spent fuel with higher atomic numbers than uranium. These TRU actinides are principally neptunium, plutonium, americium, and curium. Of these TRUs, the group of elements other than plutonium (neptunium, americium, and curium) are often referred to as minor actinides since they are present in much smaller proportions than plutonium. The plutonium content in the TRU product stream would be about 90 atom percent, with minor actinides making up the majority of the remainder (some rare earth fission products may also be present). Of the three minor actinides, two are ANM (neptunium and americium). As such, this type of nuclear material is of direct relevance as a topic for a nonproliferation impact assessment.

The DOE Office of Nuclear Energy has included ATW as one of many possible future civil nuclear energy R&D missions as a placeholder in the event that the U.S. Government decides to pursue this technology. Currently, the Department is performing technical paper studies and planning studies (*e.g.*, the "ATW Road Map") to assist Congress with fiscal and program planning. These efforts are also being reviewed by the independent Nuclear Energy Advisory Committee (NERAC) Subcommittee on the Accelerator Transmutation of Waste, which in its report of May 23, 2000, recommended that a study should be launched to identify potential proliferation concerns associated with ATW and possible approaches to mitigate identified concerns. A comprehensive nonproliferation impact assessment of the ATW program plan would be performed by the Office of Arms Control and Nonproliferation prior to proceeding beyond paper studies with actual fuels materials testing in support of ATW (or other technologies that include or imply closed fuel cycle technologies). As such, the nonproliferation impact of a possible future ATW program is not considered in this NI NIA – since it is not a well-defined, principal identified mission at this time under the Draft NI PEIS. It will, however, be considered in a future nonproliferation impact assessment if the ATW Program moves forward.

[7] Draft NI PEIS, Appendix D

2 NONPROLIFERATION POLICY BACKGROUND AND CONTEXT

In broad terms, the analysis that follows focuses on four major proliferation concerns that may be raised by the nuclear facilities and operations reviewed in the Draft NI PEIS:

- The concern that, pursuant to the Draft NI PEIS, the construction or operation of a facility in the United States that uses weapons-usable nuclear materials might encourage the development of similar facilities abroad, to the detriment of U.S. non-proliferation efforts aimed at discouraging the development of such facilities;
- The risk that weapons-usable nuclear material might be stolen from a U.S. nuclear facility constructed or operated pursuant to the Draft NI PEIS by agents of a country of proliferation concern or by a subnational organization or terrorist group;
- The risk that restrictions on voluntary or legally mandated international monitoring of certain U.S. facilities operated pursuant to the Draft NI PEIS might reduce confidence in U.S. pledges that it will never use for nuclear weapons certain weapons-usable nuclear materials that it has declared to be excess to defense needs; and
- The risk that activities proposed under the Draft NI PEIS might interfere with the implementation of anticipated future treaties, such as the Fissile Material Cutoff Treaty (FMCT).

The three weapons-usable nuclear materials whose use and processing are analyzed in this assessment, and which are discussed below, are highly enriched uranium (HEU), plutonium, and neptunium.[1] Although HEU and plutonium have long been the subject of U.S. and international nonproliferation controls, neptunium, which to date has been separated in significant quantities only in nuclear-weapon states, became the subject of international regulation only in 1999. The discussion in the following section addresses the first two of these materials; neptunium is considered in Section 2.1.8.

2.1 INTERNATIONAL NUCLEAR NONPROLIFERATION INITIATIVES AND CONTROLS

2.1.1 U.S. Leadership in the Field of Nuclear Nonproliferation

The United States has long led global efforts to prevent the proliferation of nuclear weapons and to safeguard weapons-usable fissile materials. Because the knowledge needed to make at least a crude nuclear weapon is now widespread, limited access to these essential ingredients of nuclear weapons is the principal technical barrier to nuclear proliferation in the world today. Hence, the United States has placed heavy emphasis on efforts to help monitor, protect, control, account for, and, ultimately, dispose of weapons-usable fissile materials worldwide.

Because of its pivotal role in preventing the proliferation of nuclear weapons and its own extensive nuclear programs and activities, the manner in which the United States manages its nuclear activities has a significant influence on other states. U.S. technical and policy choices frequently affect similar choices in other countries; both by example and in the way these choices support U.S. diplomatic efforts. Thus, decisions of the type analyzed in the Draft NI PEIS that are taken in the United States can positively or negatively affect efforts to enhance the global nonproliferation regime and bolster the international norm against the acquisition of nuclear weapons. In recent years, the United States has sought to make its nuclear activities increasingly transparent in order to increase international confidence in its global arms control and nonproliferation regime and to encourage similar actions by other countries.

[1] The term “plutonium” is understood in this context to mean isotopic mixtures of plutonium other than isotopically concentrated Pu-238.

2.1.2 Controlling Highly Enriched Uranium and Plutonium

The United States places high priority on efforts to control and reduce stockpiles of surplus plutonium and HEU worldwide. During the Cold War, DOE's nuclear material activities focused on the production of nuclear materials for nuclear weapons and naval fuel. Both during the Cold War and since, the United States has devoted considerable effort to ensuring that this material was secure from theft and properly accounted for. Substantial resources have been devoted to ensuring adequate domestic security and accounting systems, while correcting weaknesses in such systems that have been identified in the past. The U.S. material protection, control, and accounting (MPC&A) programs are now regarded as some of the most stringent in the world.

With the end of the Cold War, the United States stopped producing plutonium and HEU and determined that over 225 metric tons of the fissile material currently in its stockpile is excess material that will never again be used in nuclear weapons. President Clinton has directed that U.S. surplus fissile material be placed under international verification as soon as practicable and eventually be physically transformed in ways that would make it far more difficult, costly, time-consuming, and observable to ever use it in weapons again. The Department of Energy has determined that 174 metric tons of surplus HEU will be blended with other uranium to produce low enriched uranium (LEU), which cannot be used to produce nuclear weapons. About 85 percent of the LEU will be used to fuel power reactors, and the remainder will be disposed of as waste.[12] DOE will also dispose of approximately 52 metric tons of plutonium in accordance with the dual-track decision announced by DOE Secretary Hazel O'Leary in January 1997 as captured in the following statement:

> In January 1997, the Department of Energy announced that it would pursue a hybrid disposition strategy for surplus U.S. plutonium. The strategy relies on two technology approaches: irradiation, in which the surplus plutonium is converted to a mixed oxide (MOX) fuel and irradiated in existing, domestic reactors; and immobilization, in which surplus plutonium is mixed with ceramic and then surrounded by vitrified high-level radioactive waste. Both approaches will effectively convert the surplus plutonium to the “spent fuel standard” recommended by the National Academy of Sciences. In effect, the plutonium becomes as difficult, unattractive, and costly to retrieve, process, and reuse as the plutonium already residing in spent fuel from commercial nuclear reactors. Pursuing both approaches in parallel is important because it provides insurance against possible difficulties with the implementation of either technology by itself and helps ensure an early start to plutonium disposition.

In addition to these domestic efforts, the United States has a wide range of programs in place to improve controls over and ultimately reduce stockpiles of surplus weapons-usable material worldwide. Under President Clinton's September 27, 1993, Nonproliferation and Export Control Policy Statement, a key goal of U.S. efforts to prevent the spread of nuclear weapons worldwide is to "seek to eliminate where possible the accumulation of stockpiles of HEU and plutonium, and to ensure that where these materials already exist they are subject to the highest standards of safety, security, and international accountability." (See Appendix 10.2).

The United States, for example, has for decades been at the forefront of efforts to strengthen the international nuclear safeguards system administered by the International Atomic Energy Agency (IAEA) to verify that nuclear materials are not used by the nations possessing them for nuclear explosive

[12] *Federal Register,* “Record of Decision for the Disposition of Surplus Highly Enriched Uranium Final Environmental Impact Statement,” 61 Fed. Reg. 40619, 1996.

purposes. In May 1997, efforts by the United States and other nations led to international agreement on a dramatic new strengthening of the IAEA safeguards system. The agreement takes the form of a Model Protocol for Safeguards Agreements that will significantly expand the access of the IAEA to necessary information and facilities (see below). Much of the technology basic to the nuclear safeguards system worldwide is U.S. technology. The United States has also played a leading role in the development of international standards for the physical protection of nuclear materials. Additionally, the United States cooperates actively with all countries that receive U.S. nuclear exports to ensure that these nuclear materials and facilities are effectively secured.

Since the end of the Cold War, the United States and the states of the former Soviet Union have launched an unprecedented cooperative program to modernize security and accounting systems for weapons-usable materials throughout the former Soviet Union. Security and accounting for many tons of weapons-usable material have already been dramatically improved by this cooperative effort, thus directly reducing proliferation risks that could result from the theft of this material, risks that could endanger the security of the United States. If adequate funding and cooperation continue, modern security systems should be in place at all of the former Soviet facilities handling weapons-usable materials by the end of this decade.[14]

The United States also seeks to reduce Russian weapons-usable fissile material stockpiles in conjunction with efforts to eliminate its own surplus fissile materials. One particularly significant effort in this area has been the agreement to purchase 500 metric tons of HEU from dismantled Russian nuclear weapons over a 20-year period. This material is being blended down to proliferation-resistant LEU for use as commercial power-reactor fuel, reducing the risk it will ever again be used in weapons. This process provides a commercial product to the United States and provides much-needed hard currency to Russia. At the same time, the United States is actively cooperating with Russia and other countries to ensure that Russia's stockpiles of surplus weapons plutonium can be reduced in parallel with the U.S. surplus plutonium stockpile. These historic United States-Russian cooperation programs demonstrate the importance both countries place on reducing stockpiles of weapons-usable material and reducing the risk of diversion to domestic or foreign weapons programs. In addition to these initiatives, the United States is currently negotiating with Russia a twenty-year moratorium on the further accumulation of separated plutonium from civil nuclear power plant fuel. This is part of a multi-element program with Russia, announced as part of DOE’s fiscal year (FY) 2001 budget, aimed at enhancing the proliferation resistance of the civilian fuel cycle.

Along with these major efforts related to reducing stockpiles of material from weapons programs, the United States also seeks to limit the stockpiling of weapons-usable separated plutonium in civilian nuclear programs worldwide and to minimize the civil use of HEU. These efforts are discussed in further detail in the next two sections.

These programs are important complements to U.S. and international policies, such as the Nuclear Suppliers Group Guidelines, adopted by 38 nuclear exporting states, which call for restraint in the transfer of sensitive facilities, technologies, and weapons-usable materials. This includes enrichment and reprocessing facilities, equipment or technology. The United States has also played a leading role in developing international programs to limit clandestine enrichment (Iraq) and reprocessing programs (North Korea).

[14] See *Partnership for Nuclear Security*, United States Department of Energy, January 1997.

Selected Events Relating to U.S. Nonproliferation Policy and Fissile Materials

1946	Atomic Energy Act of 1946	The United States prohibited international nuclear cooperation until effective international safeguards were established.
1953	Atoms for Peace	President Dwight Eisenhower delivered his "Atoms for Peace" speech before the United Nations. He called for greater international cooperation in the development of atomic energy for peaceful purposes.
1954	Atomic Energy Act of 1954	Allowed international cooperation in nuclear energy.
1964	U.S. Off-Site Fuels Policy	The United States offered to accept, temporarily store, and chemically separate spent nuclear fuel that contained enriched uranium of U.S. origin.
1968	Treaty on the Non-Proliferation of Nuclear Weapons (NPT)	Promoted nuclear weapons disarmament and non-proliferation. Prohibited the transfer of weapons technology from nuclear to non-nuclear-weapon states.
1976	Nuclear Suppliers Group	Key nuclear supplier countries announced parallel export controls and agreed to "exercise restraint" in transfers of enrichment and reprocessing technology.
1977	Glenn-Symington Amendment Foreign Assistance Act	Stated that the United States will impose economic sanctions on non-nuclear weapon States importing enrichment or reprocessing technology, if recipient refused to accept comprehensive IAEA safeguards.
1977	Executive Order on Reprocessing	President Carter announced that the United States would stop reprocessing spent power-reactor fuel and discourage reprocessing abroad.
1978	Nuclear Nonproliferation Act	The United States strengthened nuclear export control and improved restrictions on reprocessing of U.S.-origin spent fuel.
1978	RERTR Program	The United States began the RERTR program to convert U.S. and foreign research reactors from HEU to LEU fuels.
1992	Energy Policy Act (EPACT)	The United States authorized the U.S. Enrichment Corporation to negotiate the purchase of all HEU made available by any State of the former Soviet Union.
1993	U.S./Russian HEU Agreement	The United States agreed to purchase Russian HEU.
1993	U.S. Nonproliferation and Export Policy	The United States reaffirmed that it does not encourage the use of civil plutonium and does not itself engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes.
1994	U.S. Material, Protection Control and Accounting Program	The United States launched $800 million program to help secure nuclear materials in former Soviet Union
1996	ROD on Foreign Research Reactor (FRR) program	DOE announced a renewed policy to accept foreign research reactor spent nuclear fuel containing uranium enriched in the United States.
1997	ROD on Storage and Disposition of Weapons-Usable Fissile Materials	DOE decided to dispose of a quantity of weapons-usable fissile materials in a final form that meets the Spent Fuel Standard.
2000	ROD on Siting Plutonium Disposition Facilities	Three plutonium disposition facilities will be built at Savanah River. Up to 33 MT of material will be irradiated as MOX fuel and up to 17 MT will be immobilized.

2.1.3 Reprocessing, Proliferation, and U.S. Policy

Conventional reprocessing and recycling of plutonium creates direct and indirect proliferation risks. The direct proliferation risk results from the separation, processing, and transport of quantities of material that is directly usable for nuclear weapons. The indirect risks result from setting a precedent in the United States and supporting a global industry and technical community for reprocessing.

Thus, as reiterated in President Clinton's September 1993, statement on Nonproliferation and Export Control Policy, "the United States does not encourage the civil use of plutonium and, accordingly, does not itself engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes." Under this policy, the United States will continue its commitments not to interfere with civilian nuclear programs that involve the reprocessing and recycling of plutonium in Western Europe and Japan. In regions of proliferation concern, however, the United States actively opposes plutonium reprocessing and recycling. The United States continues to explore means to limit the stockpiling of plutonium from civil nuclear programs, and seeks to minimize the civil use of HEU. Among other initiatives, the United States participated in the effort to develop an internationally agreed set of guidelines on the management of civil plutonium. In 1997, the United States reached agreement with Belgium, China, France, Germany, Japan, Russia, Switzerland, and the United Kingdom on International Guidelines for the Management of Civil Plutonium, which *inter alia* provide that each state will take into account the need to avoid contributing to the risks of proliferation and the importance of balancing plutonium supply and demand as soon as practical. The guidelines also contain a commitment to transparency in the management of plutonium. In this respect, the countries concerned have undertaken to publish statements explaining their national strategies for nuclear power and the nuclear fuel cycle, including plans for managing national holdings of plutonium, together with annual figures for their holdings of unirradiated plutonium and their estimates of plutonium contained in spent fuel.

Certain processes that would be employed under a number of alternatives discussed in the Draft NI PEIS use technologies that share attributes with conventional plutonium reprocessing or, which might be modified to permit reprocessing. Their respective potential contributions to proliferation are discussed later in this report.

2.1.4 U.S. Programs to Reduce the Risk of Nuclear Weapons Proliferation from the Civil Use of Highly Enriched Uranium

The Department of Energy has initiated two programs to help reduce the risk of nuclear weapons proliferation posed by the civilian use of fissile materials: the Reduced Enrichment for Research and Test Reactors (RERTR) program and the Foreign Research Reactor Spent Nuclear Fuel Acceptance Program.

The United States launched the RERTR program in 1978 to reduce and eventually eliminate international traffic in HEU by converting all research reactors from HEU fuels to LEU fuels, thereby reducing the potential for proliferation of HEU. Research reactors have traditionally been the main consumers of HEU in international commerce. Conversion of research reactors to LEU fuels has dramatically reduced the demand for HEU internationally. The need for the RERTR program became apparent to U.S. policy makers in the mid-1970s, when evidence suggested that increasing overseas stockpiles of research reactor spent nuclear fuel containing HEU, including those under international safeguards, presented a potential proliferation risk. A diversion of HEU could provide a potential proliferant with material that can be fabricated relatively quickly into a nuclear weapon, while providing very limited time for authorities or the international community to react. Additionally, technology was advancing to a point where the majority of research reactors, the main consumers of HEU fuel, could be converted from weapons-usable HEU fuel to LEU fuel without a significant degradation in performance. Over the past two decades, this program has proven to be an important, if not widely known, nonproliferation success story. Approximately 30 foreign reactors and 20 domestic reactors have either switched or are in the process of converting to LEU. As a result, demand for fresh HEU by foreign reactors has dropped dramatically.

President Clinton's September 1993 statement on Nonproliferation and Export Control Policy gave new emphasis to the RERTR program, reaffirming that "the United States will seek to minimize the civil use of highly enriched uranium." Increased funding for the research reactor conversion effort, including the resumption of advanced LEU fuels development, has furthered the goals of the RERTR program.

Under the 1992 Schumer Amendment, another important component of the U.S. effort to limit commerce in HEU, exports of U.S.-origin HEU for foreign research and test reactors are prohibited unless the recipient reactor operator agrees to convert the reactor to LEU fuel and targets as soon as this alternative becomes available. The prohibition can be waived only if the reactor in question can demonstrate that it cannot operate using an LEU alternative; that as soon as an LEU alternative can be used in the facility, it will be; and that the United States is actively developing an LEU alternative that can be used in place of HEU.

Another key fissile material control program is the U.S. program to accept U.S.-origin spent nuclear fuel containing uranium enriched in the United States from foreign research reactors. Beginning in the 1950s, under the Atoms for Peace Program, the United States was the primary supplier of research reactors and fuel. At first, fuel was leased to the research facility and returned to the United States. Beginning in 1964, the United States began selling fuel to foreign operators and buying it back, paying for the HEU, which the United States would recover. The fuel was traditionally reprocessed at the Savannah River Site and the uranium recycled as part of U.S. defense programs.

The initial U.S. spent nuclear fuel acceptance policy expired in 1988 for HEU containing uranium enriched in the United States, and in 1992 for LEU. In May of 1996, DOE announced the decision to begin a new program to accept spent nuclear fuel containing uranium enriched in the United States from foreign research reactors. The new acceptance policy will result in the transport of up to 20 metric tons of aluminum-based and TRIGA (training, research, isotope, General Atomics) foreign research reactor spent nuclear fuel – much of it containing HEU – to the United States. The goals of the new acceptance policy are to promote the following nonproliferation objectives:

- Ensure fuel containing uranium enriched in the United States is never diverted for use in nuclear weapons.
- Discontinue the civil use of HEU by ensuring that HEU enriched in the United States is not recycled in research reactors.
- Provide additional incentives – the offer to accept spent research reactor fuel – to encourage operators of reactors to convert from the use of HEU fuel to LEU fuel.

2.1.5 The U.S.-IAEA “Voluntary Offer” Agreement and Additional Protocol

The IAEA was established by statute in 1957 as a specialized agency of the United Nations. Under the 1970 Treaty on the Non-Proliferation of Nuclear Weapons (also referred to as the Nonproliferation Treaty or the NPT), the IAEA applies international safeguards in non-nuclear-weapon states party to the treaty to verify that their peaceful nuclear activities are not contributing to the development of nuclear explosives. Nuclear-weapon state parties are not required to accept such IAEA monitoring. Today, there are 182 non-nuclear-weapon states party to the NPT. China, France, Russia, the United Kingdom, and the United States were granted the status of nuclear-weapon states under the accord (because they had detonated nuclear explosions prior to 1967). Cuba, India, Israel, and Pakistan are the principal non-signatories to the treaty.

Although the United States is not required to accept IAEA monitoring of any of its nuclear activities or materials, it has voluntarily offered to place nuclear materials, in facilities not having national security significance, under IAEA safeguards.

Under the December 1980 *Agreement Between the United States of America and the International Atomic Energy Agency for the Application of Safeguards in the United States* (IAEA INFCIRC/228), known as the "Voluntary Offer," the IAEA is given authority to apply its safeguards at U.S. non-defense nuclear facilities to confirm that safeguarded materials there are not being used for nuclear weapons or other nuclear explosive devices. The agreement is known as the Voluntary Offer because, as a nuclear-weapon state party to the Nuclear Nonproliferation Treaty (NPT), the United States voluntarily accepted these IAEA safeguards obligations to demonstrate that it was prepared to accept the same burdens on its civilian nuclear activities as the NPT required of non-nuclear-weapon state parties.

The United States retains the right under the agreement, however, to exclude from IAEA monitoring any facility the United States deems to be engaged in activities of national security significance. To increase international confidence that it is adhering to its commitments not to use for nuclear weapons any material that it has declared excess to defense needs, the United States has announced that it will place all such formerly exempted material under IAEA inspection as soon as practicable. To date, the United States has made 75 metric tons of excess HEU and plutonium available for IAEA inspection.

Currently, all U.S. commercial nuclear power plants and many additional civilian nuclear installations are on the U.S. list of facilities eligible for IAEA inspection. The IAEA has not recently inspected any nuclear power plants (whose LEU fuel cannot be used directly for nuclear weapons) but has chosen to focus its resources instead on four installations containing weapons-usable nuclear materials that have been declared by the United States to be excess to defense needs. The inspected facilities are the Y-12 HEU storage vault at Oak Ridge, Tennessee; the plutonium storage vault at the Hanford, Washington, site; the plutonium storage vault at Rocky Flats, Colorado; and the BWXT HEU blend-down facility, in Lynchburg, Virginia. Most facilities considered under the various alternatives in the Draft NI PEIS would be eligible for IAEA safeguards under the Voluntary Offer, but some would not be placed on the "Eligible List" because they undertake certain activities to support U.S. national security needs.

Following revelations after the 1990 Gulf War that Iraq's undeclared nuclear program was far more advanced than previously imagined, the IAEA sought to strengthen its traditional safeguards system in order to improve its ability to detect clandestine nuclear activities in non-nuclear-weapon state NPT parties. Parties were asked to accept the new safeguards measures by signing an "Additional Protocol" to their Safeguards Agreements with the IAEA. To enhance the transparency of its nuclear activities, set an example for other states, and accept parallel safeguards burdens, the United States signed the US/IAEA Additional Protocol on June 12, 1998. It is identical to the *Model Protocol Additional to the Agreement(s) Between State(s) and the International Atomic Energy Agency for the Application of Safeguards,* IAEA INFCIRC/540, dated September 1997, except for the addition of two provisions that grant the United States the right to exclude facilities from IAEA safeguards for national security reasons and to protect classified information. The Protocol, expected to be submitted for the advice and consent of the Senate in early 2001, provides for expanded U.S. declarations of a wide range of nuclear-fuel cycle activities, including locations not on the U.S. Voluntary Offer Eligible List. These activities include nuclear fuel-cycle research and development, site descriptions, and information on source materials, as well as the import and export of nuclear materials and related equipment. The IAEA may request access to any location identified in the declaration; however, as a nuclear weapons State under the NPT the United States may invoke its national security exclusion at any time.

2.1.6 The Trilateral Initiative

The United States and Russia are currently negotiating a model agreement with the IAEA, under which they would agree to permit the IAEA to verify that many tons of weapons-usable material declared excess to defense needs in each country are not being used for military purposes. Unlike the U.S.-IAEA Voluntary Offer Agreement, the model Trilateral Agreement would not permit the parties to withdraw material from IAEA monitoring on the grounds of national security. The parties hope to submit the model agreement to the IAEA Board of Governors for review in late 2000.

2.1.7 Fissile Material Cutoff Treaty Negotiations

On August 11, 1998, the 802nd plenary of the Conference on Disarmament (CD) agreed to establish an *ad hoc* committee to negotiate a ban on the production of fissile materials for use in nuclear explosives. The decision was based on a December 1993 United Nations resolution on the "Prohibition of the Production of Fissile Materials for Nuclear Weapons or Other Nuclear Explosive Devices." Unfortunately, to date, the *ad hoc* committee has never been re-established after the 1998 session of the CD.

It is envisioned that, once approved by the CD member nations, the Fissile Material Cutoff Treaty (FMCT) would halt production of plutonium and highly enriched uranium (HEU) for use in nuclear explosives, or outside international safeguards. FMCT negotiations could be difficult due to two key issues: 1) how to effectively verify the ban on fissile material production for nuclear explosives, and 2) if, and then how, to address existing stockpiles of plutonium and HEU that are not currently under international safeguards.

The provisions of a future FMCT cannot be predicted. It is universally understood that, at a minimum, an FMCT will have to apply verification measures to reprocessing and enrichment facilities. There is less certainty whether, and how, irradiation facilities will be treated in an FMCT. Given the broad questions that remain concerning the treaty, this NI NIA focuses solely on the facilities where there is certainty that verification measures will apply, namely separations facilities with attributes similar to reprocessing plants.

2.1.8 Alternate Nuclear Material Monitoring Agreement

Neptunium and americium are materials that could be used in nuclear explosives. These materials are sometimes called alternate nuclear material (ANM).

ANM is produced during the irradiation of fuel in a nuclear reactor. It is produced in concentrations typically between 1 and 10% of plutonium production depending upon the degree of irradiation (higher irradiation producing greater concentrations of ANM). Usually, ANM is disposed of in high level waste in traditional spent fuel reprocessing although it can be recovered using aqueous (or other) separation methods.

Americium has significant industrial and commercial uses in sensors and detectors and neptunium is generally used as a source material for the production of Pu-238, a nuclear material with important applications as a potent heat and alpha source for radioisotope power units among other nuclear technology uses.

ANM and the IAEA. Shortly after the IAEA was created in 1957, decisions of the Agency's Board of Governors defined the elements that would be subject to IAEA safeguards, termed "special fissionable materials (SFM)." These were plutonium, highly enriched and low-enriched uranium, and uranium-233. Alternative Nuclear Materials were not included because of the negligible amounts of such material in existence at that time. In the 1980s, light-water power reactors with higher fuel exposures resulted in increasing production of ANM, sequestered in spent fuel in the fuel cycle of many countries, and the likelihood of their separation began increasing.

DOE studies by weapons scientists at Los Alamos National Laboratory highlighted the proliferation concern of ANM. This led the U.S. Government to initiate negotiations with the IAEA, other nuclear-weapon states – China, France, Russia, and the United Kingdom – and with Japan (another country with nuclear facilities potentially capable of producing and separating ANM) to control these materials before significant quantities could become available outside of the nuclear-weapon states. The negotiation process occurred over a number of years and resulted in the development of a monitoring approach, called flow sheet verification (FSV), that could be effectively implemented at reasonable cost.

International monitoring of ANM using FSV was selected by the IAEA rather than traditional full-scope safeguards because these materials do not currently pose the same proliferation risk as plutonium and HEU because of their very limited availability. FSV assures that ANM are not separated from the high-level waste stream and that safeguarded reprocessing or separation plants cannot, by design or operation, separate ANM. FSV also provides assurances that allows ANM to not be incorporated into the traditional safeguards regime provided that no significant amount of ANM is separated by a non-nuclear-weapon state. The FSV approach is based on existing IAEA safeguards at the facility and allows independent verification that ANM follows the plant design flow sheet and is not separated.[2]

On September 20, 1999, the Board of Governors of the IAEA adopted recommendations of the nuclear-weapon states and the IAEA Secretariat that it commence monitoring of neptunium and americium as ANM. Some important aspects of the adopted recommendations include:

- ANM is not statutorily considered SFM at this time and is not covered by IAEA Safeguards Agreements.
- Although the technical utility of ANM in nuclear explosives is recognized, ANM is currently not considered to be as great a proliferation concern as SFM because:
  - there is a very limited supply of ANM world-wide, and
  - the vast majority of separated ANM stocks are currently found in the five nuclear-weapon states and (in unseparated form) in Japan.
- Neptunium is subject to international nuclear export controls (Wassenaar Arrangement, Dual-Use List, Category 1, Advanced Materials). Americium is currently subject only to national export controls.
- Non-nuclear-weapon states agree to report separated inventories and transfers (or export denials) of ANM to the IAEA. Nuclear-weapon states agree to report exports of ANM to the IAEA (except for China that has opted for "observer status").
- Reprocessing plants currently under IAEA safeguards will be subject to FSV, including material sampling to verify ANM flows.

[2] Since the United States is a nuclear-weapon state and does not have any operating civil reprocessing facility under IAEA safeguards, FSV is not applicable in U.S. facilities at this time. Furthermore, FSV is not applicable to the U.S. or Russian Pu-238 production processes.

2.1.9 Vertical and Horizontal Proliferation

Vertical proliferation refers to an increase in the quantity or quality of nuclear weapons in nations that already possess them, while horizontal proliferation refers to the spread of nuclear weapons to additional states. Historically, most U.S. initiatives to limit weapons-usable nuclear materials and the facilities that can produce them have been aimed at curbing the horizontal spread of nuclear weapons. During the past decade, however, many U.S. nonproliferation efforts related to nuclear materials have sought to restrain both horizontal and vertical proliferation. U.S. programs to purchase excess HEU from Russia and to dispose of excess Russian plutonium are principally aimed reducing the risk that such materials might be stolen by terrorist organizations or agents of countries of proliferation concern. At the same time, however, these initiatives also limit the potential scale of Russia's nuclear weapons capabilities, a constraint on vertical proliferation. U.S. transparency efforts, such as the application of IAEA inspections to nuclear materials declared excess to U.S. defense needs, are similarly aimed in the first instance at constraining horizontal proliferation. They seek to buttress support for the NPT on the part of its non-nuclear-weapon state parties by demonstrating that the United States is living up to its obligations under Article VI of the treaty to end the nuclear arms race. At bottom, however, U.S. transparency measures are of interest to such other countries because they are a restraint on U.S. nuclear weapon capabilities and thus a restraint on vertical proliferation.

The FMCT is the first multilateral initiative focused on nuclear materials that seeks to constrain vertical proliferation, by capping stocks of HEU and plutonium available for nuclear weapons use. The treaty will have its principal impact on China, France, India, Israel, Pakistan, Russia, the United States, and the United Kingdom, countries that are not currently non-nuclear-weapon state parties to the NPT. The latter countries are already prohibited by that treaty from producing HEU or plutonium for nuclear weapons.

2.1.10 Roles of International and Domestic Safeguards

International Safeguards. As noted earlier, international safeguards, as implemented by the IAEA, seek to deter the national governments with jurisdiction over nuclear materials from diverting those nuclear materials from peaceful uses to nuclear explosive purposes. In the case of the United States, voluntarily accepted IAEA inspections perform this role, ensuring that materials the United States has declared will not be used for nuclear arms are not, in fact, employed for this purpose.

Whether applied in nuclear-weapon or non-nuclear-weapon states, IAEA inspections do not, however, seek to provide physical protection against theft by individuals or subnational groups – this is the responsibility of the host government. The IAEA has issued guidelines on physical protection measures to be applied by IAEA member states, but these are not mandatory. Although the international *Convention on the Physical Protection of Nuclear Materials* does impose on its parties certain physical security standards, these apply only to international shipments of nuclear materials, not to their use, processing, or storage within individual countries.[3] Thus protecting nuclear materials against theft remains a national responsibility. Material protection, control, and accounting (MPC&A) measures implemented by national governments for this purpose are referred to as "domestic" or "national" safeguards.

Domestic Safeguards. By comparison, the objective of a domestic safeguards system (*e.g.*, the safeguards system in the United States administrated by DOE and the Nuclear Regulatory Commission (NRC) for U.S. Government and commercial facilities, respectively) is for the MPC&A of nuclear material to meet national objectives. National systems protect material and facilities against theft and sabotage by individuals and subnational groups. DOE and NRC requirements for domestic safeguards at

[3] See Appendix 10.1.7.4

U.S. facilities focus on prevention of and detection of material theft or loss at the subnational level and protection against sabotage and terrorist actions.

2.2 U.S. DOMESTIC SAFEGUARDS

2.2.1 Graded Safeguards

U.S. domestic safeguards systems are "graded." That is, they place special nuclear materials into technically defined grades to permit decisions on the level of MPC&A required to safeguard the material in question. The principal focus of U.S. security measures are special nuclear materials (SNM), which has been defined as uranium enriched in U-235 above the naturally occurring level; U-233; and plutonium. DOE refers to neptunium and americium as alternate nuclear materials (ANM) and treats them as equivalent to pure U-235 for the purposes of domestic safeguards. Although the IAEA and the NRC recognize ANM and are developing policies concerning these materials, they currently do not place these materials under safeguards as SNM (or SFM, for the IAEA) in facilities where they have licensing or monitoring responsibilities.

DOE Safeguards Grades. DOE safeguards are graded on two dimensions: Category and material Attractiveness Level. Category is determined by the amount of special nuclear material of a given Attractiveness Level contained in a facility. Attractiveness Level is determined by the technical difficulty involved in preparing the material for use in a nuclear explosive. Since the technical difficulty of using a particular type of nuclear material is somewhat independent of its amount, material Attractiveness Level is determined first, followed by the Category. Since the Category is a function of the amount of material in a material balance area (MBA) or in a facility, the Category often becomes associated with the facility. For example, a facility containing more than 20 kg of 93% enriched uranium oxide would be referred to as a "Category I facility" or, more commonly, a "Cat I facility." Once the material Category is determined, the required level of domestic safeguards is also determined. See *DOE O 474.1, 8-11-99, Control and Accountability of Nuclear Materials (supersedes DOE Order 5633.3b),* and *DOE M 471.1-1, 8-11-99, Manual for Control and Accountability of Nuclear Materials* for greater detail.[4]

NRC Safeguards Grades. NRC safeguards are graded on a single dimension: Category. Category is determined by the amount of various types of special nuclear material contained in a facility. Since the Category is a function of the amount of material in a material balance area (MBA) or a facility, the Category often becomes associated with the facility. For example, a facility containing more than 5 "formula kilograms" of 93% enriched uranium oxide would be referred to as a "Category I facility" or, more commonly, a "Cat I facility." Once the material Category is determined, the required level of domestic safeguards is also determined. See*10 CFR Parts 73 and 74 and relevant NUREGs* for greater detail.[5]

2.2.2 Irradiated Materials and Radiological Self-Protection

The concept of radiological self-protection is central to discussions on theft risk reduction in the case of irradiated materials. In fact, the dose rate of irradiated materials is one of the variables for determination of material attractiveness in most regulatory frameworks covering physical protection and accounting of special nuclear materials. If a significant radiation barrier is present, the risk of theft is significantly reduced and this is generally taken into account in a graded safeguards system. For additional details on the effects of acute radiation doses on human health see Appendix 10.1.5.

[4] See Appendix 10.1.3
[5] See Appendix 10.1.4

The Spent Fuel Standard. The National Academy of Sciences recommended the Spent Fuel Standard in 1994 in considering measure for disposing of weapons plutonium. Meeting the Spent Fuel Standard means making a weapon-usable material approximately as inaccessible and unattractive for weapons use as plutonium that exists in spent nuclear fuel from commercial nuclear power reactors. Spent nuclear fuel from commercial power reactors is unattractive for several reasons, including its high radiation barrier, large size, and physical and chemical composition, which make it difficult to transport, conceal, and process. The Spent Fuel Standard is a broad target area, not a single point on an imaginary graph of proliferation resistance, and can take into account any number of factors affecting accessibility and attractiveness. In the *January 21, 1997, Record of Decision for the Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement (62 Federal Register 3014),* DOE adopted the Spent Fuel Standard specifically for the disposition of weapons-usable fissile materials.

3 ASSESSMENT EVALUATION FACTORS AND METHODS

3.1 EVALUATION FACTORS

To evaluate the missions described in the Draft NI PEIS, nonproliferation assessment factors are defined to analyze the consistency between stated missions, facilities, alternatives and options and U.S. nonproliferation policy, U.S. laws and regulations, and international agreements. The criteria applied in evaluating these implications fall into two main categories: technical factors and policy factors. Technical factors assess the theft and diversion risk and technical attractiveness (as a source of nuclear weapons material) of nuclear materials that are associated with missions and facilities described in the Draft NI PEIS. Policy factors assess the international and domestic political and legal effect that U.S. decisions might have on current and future nuclear nonproliferation efforts.

Each of the technical and policy factors will be weighed in judging the nonproliferation merits of each identified facility or alternative. Where appropriate, potential actions that can be taken to mitigate proliferation uncertainties and concerns are also addressed.

3.1.1 Technical Factors

The three technical factors used in this assessment focus on assuring that nuclear material, in conjunction with any of the proposed missions, facilities, alternatives, and options are physically difficult to either steal or divert, and that this material and associated processes are appropriately safeguarded. Such safeguards would then have the effect of assuring security to prevent theft and would bestow transparency to give assurances against diversion. The three technical factors include the degree to which use of a particular mission, facility or implementation of a particular alternative would be:

Assuring Against Theft or Diversion. This includes an assessment of the attractiveness of nuclear material to potential overt or covert theft with respect to its characteristics both during and after any activities described for a given mission, facility, alternative or option. In particular, this factor considers the type and concentration of nuclear material, the total amount of nuclear material, the concealability and transportability of discrete items containing nuclear material, the security of the material and facilities, and how easy it is to provide for a complete accounting of the nuclear material. Considerations in assessing the ease of material accountability are whether the involved facilities can be placed under international safeguards, whether the material is present in bulk form or as discrete items, and any processing steps that might result in material unaccounted for.

Facilitating Cost-Effective International Monitoring. This factor considers how easily international safeguards might be implemented on the described material and facilities. Are facilities under consideration eligible for international safeguards under the U.S. Voluntary Offer?[1] If facilities are not eligible, is there a national security imperative that would exempt the facility from the U.S. Voluntary Offer? This factor also includes whether the facilities, if already existing, are designed and constructed in a manner to accommodate provisions for safeguarding and accountancy. Factors such as radiation and contamination that may prevent a design verification of a facility also are considered. This factor also considers whether facility material accountancy is reasonably possible.

Resulting in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. This factor considers the radiation barrier and the chemical/physical form of the final

[1] See Section 2.1.5

nuclear materials produced by each facility. Do operations in a given facility reduce or increase the safeguards grade of nuclear materials?[2] It considers whether the radiation barrier on the final forms is high enough to require remote handling and processing, and it considers the level of investment, time, and sophistication that would be required to extract fissile material from the form.[3]

3.1.2 Policy Factors

The four policy factors used in this assessment focus on the ability of the United States to maintain and strengthen international efforts to stem the spread of nuclear weapons (horizontal proliferation), including the overall approach to limit, restrict, and minimize the use of weapons-usable material in the civilian nuclear fuel cycle and in other civilian applications. Furthermore, the policy factors also address the continued transparency of the U.S. domestic moratorium on fissile material production for nuclear weapons (vertical proliferation). For example, implementing an alternative that does not promote or involve the use of proliferation prone technologies to produce weapons-usable material might help reduce the risk associated with proliferation of these technologies. The United States should avoid decisions that might offer proliferants additional arguments and justifications for their activities. Conversely, alternatives that allow for research in proliferation solutions, while implementing stringent standards of domestic safeguards in management of nuclear material might positively influence implementation of the nonproliferation agenda, reducing proliferation risks. The four policy factors include the degree to which use of a particular mission, facility or implementation of a particular alternative would be:

Maintaining Consistency with U.S. Nonproliferation Policy. This factor considers all elements of existing U.S. nuclear nonproliferation policy including the 1993 Nonproliferation Policy Statement, the Schumer Amendment, relevant U.S. laws and regulations, and international agreements.[4] This factor considers whether the missions or facilities involve plutonium reprocessing, unnecessary use of highly enriched uranium (HEU) in civil fuel cycle activities, or abridge U.S. commitments as articulated in international agreements.

Avoiding Encouragement of Plutonium Reprocessing. This factor assesses whether U.S. actions would strengthen other nation's arguments, leverage, or negotiating positions with respect to maintaining or increasing their programs for plutonium reprocessing outside "existing [U.S.] commitments regarding the use of plutonium in civil nuclear programs in Western Europe and Japan."[5]

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. This factor considers whether the alternative involves fissile material processing in a manner in which separated weapons-usable SNM is produced or current or former weapons production processes and facilities are used. International transparency measures, that may be available at a facility, are also considered as mitigation under this factor.

Supporting Negotiation of a Verifiable Fissile Material Cutoff Treaty (FMCT). This factor considers whether the missions or facilities include plutonium reprocessing or uranium enrichment, and if so, whether the facilities involved are technologically compatible with the application of international monitoring that might be required to form the verification mechanism of an FMCT. It also considers the degree to which implementation of the particular alternative under the specific proposed circumstances could affect facility operations.[6]

[2] See Section 2.2.1
[3] See Section 2.2.2
[4] See Section 2.1 and Appendix 10.1.7
[5] See Appendix 10.2
[6] See Section 2.1.7

3.2 EVALUATION GRADING SCALE

A qualitative grading scale on three levels is defined to indicate the degree to which particular missions, facilities, alternatives, or options meet U.S. nonproliferation objectives. The three levels in the grading scale are:

● ***Fully Meets Nonproliferation Objectives.*** A mission, facility, alternative, or option under a factor assessment *fully meets nonproliferation objectives* if: there *are no significant identified concerns* that can be raised demonstrating how, within the bounds of the description given in the Draft NI PEIS, the use of the facility or implementation of the alternative is contrary to U.S. nonproliferation objectives as defined by the assessment factor.

◑ ***Might Raise Nonproliferation Concerns.*** A mission, facility, alternative, or option under a factor assessment *might raise nonproliferation concerns* if: there *is significant uncertainty* as to whether, within the bounds of the description given in the Draft NI PEIS, the use of the facility or implementation of the alternative *might have an adverse effect* on U.S. nonproliferation objectives as defined by the assessment factor.

○ ***Raises Nonproliferation Concerns.*** A mission, facility, alternative, or option under a factor assessment *raises nonproliferation concerns* if: there *are significant identified concerns* that can be raised demonstrating how, within the bounds of the description given in the Draft NI PEIS, the use of the facility or implementation of the alternative is contrary to U.S. nonproliferation objectives as defined by the assessment factor.

3.3 EVALUATION METHODS

3.3.1 Facility Assessments

This nonproliferation impact assessment evaluates each of the missions, facilities, alternatives, and options described in the Draft NI PEIS. The evaluation method used begins with individual facility assessments. Each facility and its proposed missions are briefly described, the relevant nuclear materials are discussed, and the evaluation factors are analyzed and graded (see the above definitions and discussion of evaluation factors and grading scale). In some cases, where deemed necessary to assist the reader's understanding of complex issues, additional technical and policy context is added and discussed. Footnotes are used extensively both for references and to provide additional details for the interested reader.

3.3.2 Alternative and Option Assessments

Following the evaluation of each facility, each alternative and option is evaluated by using a "weak link" vulnerability analysis of the facility and transportation assessments. Since any specific option under a given alternative is constructed of various facilities (and related missions) plus transportation between facilities, the weakest link in the series of facilities (and transportation) is assigned to represent the overall assessment for the option in question. The analogy being that a chain (of facilities and activities in this case) under stress breaks at the weakest point such that the weak link represents the total strength of the entire chain. Following this analogy, each of the facility evaluations (including the described mission elements), associated with a given option, are placed side by side, along with the transportation evaluation, and for each evaluation factor the weakest grade is selected to represent the grade for the evaluated option. In this manner, the nonproliferation assessments of the alternatives and options are "rolled-up" from the facility and transportation assessments.

As a hypothetical (and very extreme) example of the weak link vulnerability analysis approach, imagine the following scenario: assume that 99 different facilities engage in proliferation risk-free operations over a given time frame as part of large nuclear infrastructure system but in one activity, at a single facility (the 100^{th} facility), more than a significant quantity of 90% enriched HEU is covertly stolen by an employee (who promptly disappears) as a result of a weakness in the facility's domestic safeguards system. Then suppose that the thief sells the material to a subnational terrorist organization. Further suppose that the now endowed terrorist organization fashions a crude improvised nuclear device and smuggles that device into the United States, plants and then detonates the device in a metropolitan area. Although the yield of the device turns out to be significantly less than one kiloton, a national catastrophe has occurred. At this point in the thought experiment, would it matter that the weakness was in only 1% of the links or that the weakest link broke and disaster was the consequence?

It is because of this extreme level of weak link threat that Category I facilities that house "strategically significant" quantities of weapons grade material have multi-layered defense in-depth domestic safeguards systems that are continuously upgraded and under constant scrutiny. Multiple layers of these elaborate systems must fail simultaneously in order for a breach to occur. The weak link analysis method is sound and conservative since the weak links are the most vulnerable in an adversary perspective analysis.

Assessment results are then summarized and presented as conclusions and recommendations. The most favorable alternatives and options are listed as well as the least favorable. Approaches to help mitigate proliferation concerns are also summarized and presented. The overall missions (independent of selected facilities) proposed in the Draft NI PEIS are evaluated by using a "most favorable realizable path" analysis. The analogy being that if attainment of a goal is desirable but may be pursued along several different paths, the most favorable realizable path is most representative of the minimum "cost" in a cost/benefit analysis of attaining the goal. The minimum nonproliferation impact is the "cost" consideration in a nonproliferation impact assessment. As a result, a proposed mission is assessed to be equivalent to the most favorable nonproliferation option that accomplishes that mission.

4 ASSESSMENT OF THE FAST FLUX TEST FACILITY

4.1 FACILITY AND MISSION DESCRIPTION

A restart of the Fast Flux Test Facility (FFTF) is proposed in Alternative 1, Options 1-6, to support the irradiation requirements of three of the proposed missions in the Draft NI PEIS:

- Medical, industrial and research isotope production.
- Pu-238 production to meet NASA program requirements (minimum production of 5 kilograms [kg] per year).
- Civil nuclear energy research and development (R&D).

The FFTF is a 400 megawatt thermal (MWt), liquid sodium cooled nuclear test reactor located at the Department's Hanford Site. FFTF was originally brought online in 1980 to serve as a testbed for the now discontinued U.S. Liquid Metal Fast Breeder Reactor (LMFBR) program. It has also been used to test advanced nuclear fuels and systems, as well as to produce medical and industrial isotopes and tritium for fusion research.[1]

The FFTF complex includes the reactor, as well as equipment and structures for heat removal, containment, core component handling and examination, fuel off-loading and storage, supplying utilities, and other essential services. The central feature of FFTF is the reactor containment building, an all-welded cylindrical steel structure 135 feet in diameter and 187 feet high. The reactor is located in a shielded cell in the center of the containment structure. Heat is removed from the reactor by circulating liquid sodium under low pressure through three separate closed primary piping systems, referred to as loops, which include pumps, piping, and intermediate heat exchangers. These loops are located within cells, filled with inert gas, within the containment structure. The secondary sodium loops transport reactor heat from the intermediate heat exchangers to the air-cooled tubes of the dump heat exchangers. From there the heat dissipates into the atmosphere. Unlike commercial nuclear power reactors that use reactor heat to generate steam to produce electricity, FFTF has no capability to generate electricity.

FFTF has demonstrated its capability to function successfully as a nuclear science and irradiation services user facility. It has five distinct features: size, flux, test evaluation and irradiation capabilities, fuel type, and coolant type.

Size: FFTF is the Department's newest and largest test and irradiation services reactor. It is the largest liquid-metal test reactor in the world. Capable of operating at power levels from 100 to 400 MWt, the facility has a larger volume to accommodate testing and irradiation services than the combined volume of the Department's other operational reactors.

Flux: FFTF is a fast flux reactor. A fast flux reactor uses high-energy neutrons in the fissioning process. Although FFTF produces neutrons primarily in the fast spectrum, neutron energy levels can be tailored through the use of hydride-moderated targets to produce neutrons across the fast, epithermal, and thermal spectra. This design feature provides a broad spectrum of neutron energies, as well as a high flux density (up to 7×10^{15} neutrons per square centimeter per second).

[1] *Program Scoping Plan for the Fast Flux Test Facility: A Nuclear Science and Irradiation Users Facility,* Pacific Northwest National Laboratory, August 1999.

Test evaluation and irradiation capabilities: FFTF was designed and operated as a test and irradiation service facility with the ability to fully instrument and test in-reactor experiments while varying the conditions experienced in those individual tests. In addition, FFTF's configuration allows the addition of a gas loop for the production of gaseous isotopes and up to seven rapid retrieval systems for the production of short-lived isotopes.

Fuel: FFTF has demonstrated its ability to use and test plutonium-based fuels, and also has the ability to use highly enriched uranium (HEU) fuel. Fuel options and the possibility of low enriched uranium (LEU) fuel for FFTF operations are discussed in the section 4.2.1.

Coolant: FFTF is currently the only operational reactor in the United States that uses liquid sodium metal as a coolant. The United States has previously operated other reactors with sodium coolant but these reactors have been deactivated.

The planning assumption for FFTF is to produce 5 kg Pu-238 per year. FFTF could be used in combination with any one of the three processing facilities proposed for the Pu-238 production mission. In addition, FFTF could produce all of the proposed isotope products and provide irradiation services for civil nuclear energy R&D programs. The proposed FFTF neptunium target design is an assembly that contains 19 large diameter pins that combine alternating thin pellets or wafers of neptunium dioxide and yttrium hydride moderator within steel alloy cladding.[2]

4.2 NONPROLIFERATION ASSESSMENT

4.2.1 Relevant Nuclear Materials

FFTF is currently designed to operate using mixed oxide (plutonium-uranium oxide or, more commonly, MOX) fuel; however it can also be operated using HEU fuel. FFTF has an onsite supply of MOX fuel for approximately 6 years of operation at 100 MWt (hereafter referred to as Hanford MOX fuel). When this onsite fuel is depleted, FFTF may continue to use MOX fuel or may switch to a reactor core of HEU fuel if alternative LEU fuel is technically infeasible. DOE believes that an additional 15-year supply of MOX fuel would be available from Germany under favorable economic terms (hereafter referred to as German MOX fuel). This fuel would be reconfigured into assemblies suitable for irradiation at FFTF before shipment to the United States Thus, the Draft NI PEIS evaluates the 35-year operation of the FFTF for two reactor core configurations: 1) operation of a MOX core for approximately 21 years followed by 14 years of operation with a HEU core, and 2) operation of a MOX core for approximately 6 years followed by 29 years of operation with a HEU core. Since the technical feasibility of LEU fuel has not yet been established and its environmental impact is bounded by the use of HEU fuel, the use of LEU fuel was not evaluated as a formal option in the Draft NI PEIS. Nonproliferation assessments of each FFTF fuel type and target and product materials are discussed below.

4.2.1.1 HANFORD MOX FUEL

Under Alternative 1, Options 1-6 of the Draft NI PEIS, existing fresh Hanford MOX fuel is the intended fuel supply for the FFTF for a period of about 6 years following restart of the FFTF. The plutonium content in the Hanford MOX fuel was originally transferred for use in FFTF by the U.S. Atomic Energy Commission (AEC) as excess defense programs material. Since this fuel is currently stored at the FFTF site and the fuel was originally designed, fabricated, licensed and procured for use in FFTF, there is no

[2] Draft NI PEIS, Chapter 2

requirement for reprocessing or MOX fuel fabrication in order to use this existing plutonium fuel source. The Hanford MOX fuel has a plutonium oxide fraction (by oxide mass) between 23 and 29%.

The Hanford MOX fuel is currently in DOE custody. As such, it is subject to DOE Orders regarding material protection, control and accounting (MPC&A). Under DOE safeguards, the fresh Hanford MOX fuel is Category I, Attractiveness Level C (High-Grade Materials).[3] Category I, Attractiveness Level C is the highest DOE safeguards grade given to oxide reactor fuel. Following irradiation, the spent MOX fuel would likely be Category IV, Attractiveness Level E (All Other Materials), which is the lowest DOE safeguards grade, as a result of the significant radiological barrier.[4] Furthermore, The FFTF and its fuel storage facility are on the eligibility list for the U.S. Voluntary Offer. The IAEA may elect to place the Hanford MOX fuel and the FFTF under IAEA safeguards as provided for under the U.S. Voluntary Offer and the Additional Protocol.[5]

Use of the Hanford MOX fuel in FFTF is not contrary to established U.S. nonproliferation policy in this case. The mitigating factors of this case follow:

- The Hanford MOX fuel will not require reprocessing or fuel fabrication either before or after use in order to meet U.S. programmatic needs.
- The Hanford MOX fuel contains plutonium that was transferred by the AEC for use in FFTF that was judged to be excess to defense needs. As such, disposition of this existing MOX fuel in a nuclear reactor is fully consistent with U.S. policy regarding the disposition of excess defense plutonium.
- U.S. programmatic use is not reasonably expected to encourage reprocessing as a collateral consequence in any other country.
- The material will remain eligible for international safeguards via the U.S. Voluntary Offer.
- The material will remain subject to DOE Orders defining physical protection standards and material accounting that assure against material theft.

The circumstances of the Hanford MOX fuel are unique from a nonproliferation point of view in that the fuel is currently the property of U.S. Government, which has cancelled its LMFBR and reprocessing programs. Since the cancellation of the LMFBR program, the fresh Hanford MOX fuel has become an enduring disposition legacy awaiting resolution by the U.S. Government. Regardless of whether FFTF is restarted, the Hanford MOX fuel will require eventual disposal either by conversion to spent fuel through irradiation in a reactor or by some other method such as immobilization and direct disposal. Bulk material handling would be required if immobilization technologies are considered (such as can-in-can). Disposition through irradiation in FFTF would not require chemical or bulk processing. Given the composition of the Hanford MOX fuel, chemical processing would be required to reduce the plutonium concentration of the fuel for disposition in a light water reactor (LWR).[6]

If a decision is made to restart FFTF, the Hanford MOX fuel could serve an immediate civil nuclear programmatic interest of the U.S. Government and at the same time dispose of a significant stockpile of highly attractive fresh plutonium fuel by conversion to spent fuel through irradiation in FFTF. Furthermore, given that the Hanford MOX fuel is the standard fuel design for the FFTF, its disposition in FFTF represents a safe, low-cost, high benefit opportunity to reduce the U.S. stockpile of separated civil plutonium without chemical or bulk processing. As such, this represents an opportunity to exercise established U.S. policy as stipulated in the 1993 Nonproliferation and Export Control Policy Statement:[7]

[3] See Appendix 10.1.3
[4] See Section 2.2.2
[5] See Section 2.1.5
[6] Disposal in LWRs is not currently under consideration for the Hanford MOX fuel.
[7] See Appendix 10.2

The U.S. will explore means to limit the stockpiling of plutonium from civil nuclear programs…

If FFTF is restarted, disposal of the Hanford MOX fuel in FFTF would fulfill this policy directive by affecting an immediate reduction in the U.S. stockpile of separated plutonium.

4.2.1.2 GERMAN MOX FUEL

Under Alternative 1, Options 1-3 of the Draft NI PEIS, German MOX fuel is the intended fuel supply for the FFTF for a period of about 15 years following the use of Hanford MOX fuel. Since this fuel is currently stored in Dounreay, Scotland and Hanau, Germany, its use in FFTF would require that the fuel be imported to the United States.

The German MOX fuel assemblies have a fuel pin design that may allow the pins to be used intact as FFTF fuel pins. In order to load the fuel into the FFTF, the pins would require repackaging into assemblies engineered for use in the FFTF. The fresh German MOX fuel is IAEA Category I nuclear material currently in European Atomic Energy Community (EURATOM) safeguards custody, subject to the highest levels of international physical protection standards and safeguards.[8] Under DOE safeguards, the fresh German MOX fuel is Category I, Attractiveness Level C (High-Grade Materials).[9] Category I, Attractiveness Level C is the highest DOE safeguards grade given to oxide reactor fuel. Following irradiation, the spent MOX fuel would likely be IAEA Category II nuclear material. DOE would likely grade the spent fuel as Category IV, Attractiveness Level E (All Other Materials), which is the lowest DOE safeguards grade, as a result of the significant radiological barrier.[10]

Since the German MOX fuel is currently under EURATOM safeguards, it would be physically protected and accounted for according to EURATOM standards during all operations prior to and during shipment from Europe to the United States EURATOM safeguards are subject to IAEA oversight through IAEA/EURATOM agreements that allow the IAEA to perform either independent monitoring, joint monitoring or to act in an observer status depending upon the particular technical situation.

Any importation of EURATOM safeguarded MOX to the United States would be encumbered by the U.S.-EURATOM Agreement for Cooperation.[11] This agreement stipulates peaceful use and that physical protection must be applied to the material and that the material must remain eligible for IAEA safeguards under the U.S. Voluntary Offer. The FFTF and its fuel storage facility are on the eligibility list for the U.S. Voluntary Offer. Because of IAEA/EURATOM responsibilities to insure the integrity of these agreements, the IAEA may elect to place the fuel and the FFTF under IAEA safeguards as provided for under the U.S. Voluntary Offer and the Additional Protocol. [12]

If the IAEA decides not to place the FFTF and the transferred German MOX fuel under IAEA safeguards, the Department would still be obliged to be in scrupulous compliance with the Agreement for Cooperation, which requires that the United States provide an annual report to EURATOM showing the total amounts (by type) of EURATOM origin fissile material that are in U.S. custody. The German MOX fuel would be declared annually as part of this accounting report.

[8] See Appendix 10.1.7.4
[9] See Appendix 10.1.3
[10] See Section 2.2.2
[11] See Appendix 10.1.7.4
[12] See Section 2.1.5

While an importation of a substantial amount of fresh MOX fuel into the United States for use in a DOE civil nuclear program is unprecedented, it is not contrary to established U.S. nonproliferation policy in this case. The mitigating factors of this case follow:

- The German MOX fuel will not require reprocessing either before or after use in order to meet U.S. programmatic needs.
- US programmatic use is not reasonably expected to encourage reprocessing as a collateral consequence either in Germany or in any other country.
- The material will remain eligible for international safeguards via the U.S. Voluntary Offer.
- The material will remain subject to international peaceful-use and physical protection and accounting standards that prevent its use for nuclear explosive or military purposes and insure against theft and diversion.

The circumstances of the German MOX fuel are unique from a nonproliferation point of view in that the fuel is currently the property of Germany, which has cancelled its fast reactor program, cancelled its reprocessing program and is considering an eventual moratorium on all domestic nuclear energy production. Since the cancellation of the German fast reactor program, the German MOX fuel has become an enduring disposition legacy awaiting resolution by the German government. Regardless of whether FFTF is restarted, the German MOX fuel will require eventual disposal either by conversion to spent fuel through irradiation in a reactor or by some other method. Given the composition of the German MOX fuel, chemical processing would be required to reduce the plutonium concentration of the fuel if it were decided that disposition in an LWR is preferable. Bulk processing would be required if other immobilization technologies are considered (such as can-in-can). Disposition through irradiation in FFTF would not require chemical or bulk processing.

If a decision is made to restart FFTF, the German MOX fuel could serve an immediate civil nuclear programmatic interest of the U.S. Government and at the same time dispose of a significant stockpile of highly attractive fresh plutonium fuel by conversion to spent fuel through irradiation in FFTF. Furthermore, given that the German MOX is ideally suited to fuel FFTF with a minimum amount of re-engineering, its disposition in FFTF represents a safe, low-cost, high benefit opportunity to reduce the German stockpile of separated civil plutonium without chemical or bulk processing, or development of immobilization technology. As such, this represents an opportunity to exercise established U.S. policy as stipulated in the 1993 Nonproliferation and Export Control Policy Statement:[13]

> The U.S. will explore means to limit the stockpiling of plutonium from civil nuclear programs, and seek to minimize the civil use of highly-enriched uranium.

If FFTF is restarted, disposal of the German MOX fuel in FFTF would fulfill this policy directive in two ways:

- by affecting a substantial reduction in the German stockpile of separated civil plutonium, and
- by minimizing the possible use of HEU fuel in the out-years of FFTF operation, in the event that alternative LEU fuel is found to be technically infeasible by the Department's Reduced Enrichment Research and Test Reactor (RERTR) Program.

[13] See Appendix 10.2

4.2.1.3 OUT-YEAR FUEL ALTERNATIVES

HEU fuel (30 to 37% enriched) is analyzed as the current assumed fuel supply for FFTF operations beyond the use of MOX fuel in all FFTF restart options (Alternative 1, Options 1-6) presented in the Draft NI PEIS. The proposed FFTF restart timeline shows uranium fuel use beginning in 10 to 25 years following the Record of Decision depending upon whether German MOX fuel is imported and available for use in FFTF. The existing FFTF HEU oxide fuel design requires uranium enriched to between 30 and 37%. Under international definitions, uranium enriched to or above 20% in the U-235 isotope is HEU.

HEU fuel for FFTF would be under DOE custody. As such, it is subject to DOE Orders regarding physical protection and material accounting. Under DOE safeguards, fresh FFTF HEU fuel is Category II, Attractiveness Level D (Low-Grade Materials).[14] Following irradiation, the spent HEU fuel would likely be Category IV, Attractiveness Level E (All Other Materials), which is the lowest DOE safeguards grade, as a result of the significant radiological barrier.[15]

Although not identified in the Draft NI PEIS, if 30 to 37% enriched HEU fuel is procured for out-year use in FFTF, that HEU fuel would likely be fabricated at one of two facilities currently NRC licensed to produce HEU fuel in the United States: BWX Technologies, Inc. or Nuclear Fuel Services, Inc.

LEU fuel (slightly less than 20% enriched) will be considered for use in FFTF by the DOE RERTR Program. In the event that it is feasible to operate the FFTF on LEU fuel, LEU fuel would be fabricated for FFTF and would be in DOE custody. As such, it would be subject to DOE orders regarding physical protection and material accounting. Under DOE safeguards, fresh FFTF LEU fuel would be Category IV, Attractiveness Level E (All Other Materials). Following irradiation, the spent LEU fuel would remain Category IV, Attractiveness Level E (All Other Materials).

The FFTF and its fuel storage facility are on the eligibility list for the U.S. Voluntary Offer. The IAEA may elect to place HEU or LEU fuel and the FFTF under IAEA safeguards as provided for under the U.S. Voluntary Offer and the Additional Protocol.[16]

Under established U.S. nonproliferation policy, the U.S. seeks “to minimize the civil use of HEU.”[17] Furthermore, research and test reactors, fueled by HEU must be converted to LEU fuel unless certain requirements are met:[18]

- An existing research or test reactor can operate using HEU fuel if it can be demonstrated that the reactor can not operate using LEU fuel, or
- the reactor is currently in the process of being converted (or studied for conversion) to LEU fuel but must use HEU fuel until the conversion is complete, or
- the use of LEU fuel would significantly curtail the execution of the reactor’s mission, or
- the use of LEU fuel would greatly increase the cost of operating the reactor.

The development and qualification of alternative LEU fuels is the responsibility of the Department’s RERTR Program. In the event that a Record of Decision indicates that FFTF should be restarted, the RERTR program will perform a technical study to determine the feasibility of fueling FFTF with an alternative LEU fuel in the out-years following the use of MOX fuel. This technical study would include

[14] See Appendix 10.1.3
[15] See Section 2.2.2
[16] See Section 2.1.5
[17] See Appendix 10.2
[18] See Appendix 10.1.7.2 and 10.3, Schumer Amendment

the full scope required by the program: technical feasibility including reactor mission impact and cost impact. If it is determined that LEU fuel is feasible, further projects would be undertaken to develop, test and procure the LEU fuel.

In the event that it is determined, by the RERTR program, that an alternative LEU fuel is not technically feasible as a fuel supply for FFTF, then the use of HEU fuel would be consistent with U.S. nonproliferation policy. Since U.S. nonproliferation policy indicates the legitimate path to identify and procure FFTF out-year uranium fuel supplies and a technical program exists to support that policy directive, uranium fuel can be procured for FFTF in a manner consistent with U.S. nonproliferation policy regardless of the technical outcome of an RERTR study on LEU fuel. Furthermore, since the chemical nature of HEU and LEU are identical and HEU has higher nuclear reactivity, it has been determined that HEU bounds the environmental impact analysis for the case of uranium FFTF fuel. As such, a formal technical decision from RERTR on the feasibility of LEU fuel for FFTF is not a prerequisite for issuance of either the Final NI PEIS or the Record of Decision.

Excess defense origin plutonium is not available for production of additional MOX fuel for the FFTF. All stocks of excess defense plutonium (current and future) covered by the Department's Plutonium Disposition Program, which are intended for reactor disposition, will be converted into MOX for LWRs as stipulated in bilateral agreements between the United States and the Russian Federation. As a result, there would be no further *domestic* supply of MOX fuel for FFTF following the use of the existing Hanford MOX fuel.

4.2.1.4 OTHER RELEVANT NUCLEAR MATERIALS

Under DOE safeguards, fresh neptunium targets for Pu-238 production are treated as equivalent to material containing an equal concentration of pure U-235. As such, neptunium targets would be treated as Attractiveness Level C (High-Grade Material) under DOE safeguards.[19] The DOE safeguards Category, for material balance areas containing neptunium targets, varies with the mass of neptunium present. The appropriate level of DOE safeguards will be applied to all neptunium operations. Irradiated neptunium targets would be treated in the same manner as spent fuel. That is, if the targets are at or above 100 REM per hour at 1 meter, they would be treated as Category IV, Attractiveness Level E (All Other Materials), and if they are below the spent fuel standard they would be treated either as moderately irradiated material or similar to a fresh target.

Other isotope production targets and products, as defined in the Draft NI PEIS, are not considered special nuclear material (SNM) and are not subject to DOE safeguards except as required for property protection. Many of the isotopes under consideration for production are extremely radioactive (such as Co-60) and are subject to stringent controls and regulations to protect the health and safety of workers and the general public but these regulations are not associated with proliferation prevention.

Civil nuclear energy R&D materials and fuels that are stored or irradiated at the FFTF would be subject to the same controls and regulations discussed above for SNM fuels and ANM targets. As such, the above discussion is inclusive of these materials.

4.2.2 FFTF and Liquid Metal Fast Reactor Questions and Answers

During the public scoping meetings for the NI PEIS, a commentator stated with some concern that FFTF was a "breeder reactor." This same concern has been raised in several letters received by the Department

[19] See Appendix 10.1.3

from concerned groups and citizens. To address this concern a brief technical discussion is required. First, the expressed concern can be laid to rest: the FFTF was not designed to be a breeder reactor, the FFTF has never been operated as a breeder reactor, and the Department has no plan or intention to operate FFTF as a breeder reactor in the future. To explain the technical reasons and qualifications that lead to this statement requires an explanation of what a breeder reactor is, why FFTF is not a breeder reactor, and whether and under what circumstances it might be possible to convert FFTF to operate as a breeder reactor. Furthermore, the technical and policy implications of converting FFTF to operate as a breeder reactor are also discussed.

4.2.2.1 WHAT IS A BREEDER REACTOR?

A reactor that operates in a breeding mode is one that produces more fissile material than it consumes during its operation. In other words, as the reactor operates, the total amount of fissile material in the reactor core increases with time. It is common to quantify the mode of reactor operation by calculating a number called the breeding ratio. The breeding ratio is the mass production rate divided by the mass consumption rate of fissile material in the reactor. Therefore, when the breeding ratio of a reactor is equal to one, the reactor is producing exactly as much fissile material as it consumes so that the total amount of fissile material does not change with time during equilibrium reactor operation. Such a reactor is said to be operating at "breakeven." If the breeding ratio is less than one the reactor consumes more fissile material than it produces and the reactor is in a "burning" mode of operation. If the breeding ratio is greater than one the reactor is producing more fissile material than it consumes and the reactor is operating in a "breeding" mode and we refer to that reactor as a "breeder reactor."

In order to have breeding ratio greater than one, for the production of Pu-239 from fertile U-238, a reactor that operates in the fast neutron spectrum is required. Such a reactor is called a "fast reactor." In a fast reactor, it is possible to have a "neutron economy" that has sufficient excess neutrons available for capture in a depleted uranium blanket so that each fission reaction results, on average, in more than one neutron capture in a U-238 nucleus. Furthermore, since plutonium fuels can produce more excess neutrons than enriched uranium fuels, breeder reactors typically use plutonium driver fuel. Although thermal neutron spectrum reactors such as graphite or heavy water reactors can be very efficient plutonium producers, their breeding ratios are always less than one.

Of the hundreds of operating reactors around the world, nearly all are operating in a burning mode. That is, they consume more fissile material than they produce. This does not mean that plutonium is not produced in large quantities sequestered in spent nuclear fuel, but that less plutonium is produced than U-235 or MOX fissile species are consumed in those operating reactors. Uranium enrichment services are required to make up the net consumption of fissile material in reactors worldwide. Only a very small number of liquid metal fast reactors (LMFRs) have actually operated in a breeding mode – one reactor in Japan (Monju) and two reactors in France (Phoenix and Super Phoenix). Although other countries (including the United States) have developed the technology required, no reactor in these countries has operated in a breeding mode.

The LMFBR closed fuel cycle was originally conceived of as a strategy to minimize the use of uranium in the fuel cycle while limiting plutonium production to remain in proportion to nuclear electricity generation requirements.[20] Since LMFRs can be designed to operate as actinide burners, at breakeven, or

[20] This is in contrast to the open once-through LWR fuel cycle that is producing rapidly increasing stocks of plutonium, at a rate of about 250 g-Pu/MWe-year, sequestered in spent fuel. The total increase in U.S. civil plutonium stocks in spent nuclear fuel increases by about 25 metric tons (25,000 kg) heavy metal per year. An estimate of the total inventory of U.S. civil plutonium in spent fuel as of the year 2000 is 360 metric tons heavy metal. The worldwide civil plutonium inventory in the year 2000 is estimated at 1,380 metric tons heavy metal. For estimates see Albright, D., et. al., *Plutonium and Highly Enriched Uranium 1996*, SIPRI, Oxford University Press, 1997, Chapter 5.

as breeder reactors, the amount of plutonium inventory in the fuel cycle could be adjusted to match energy production needs while retaining the majority of the plutonium inventory in operating reactor cores.

Plutonium fueled LMFRs use very little uranium. Since LMFBRs do not burn U-235 and they directly convert U-238 into fissile Pu-239, there is no need for enrichment services and uranium use by the LMFBR closed fuel cycle could be as little as 0.7% of the total uranium mass requirements of an open once-through LWR fuel cycle with equivalent electricity generation.[21] The closed LMFBR fuel cycle would also generate about 0.2% of the total uranium mass as waste materials (with a corresponding massive reduction in total nuclear waste volume and radiotoxicity) when compared to the open once-through LWR fuel cycle.[22]

Furthermore, LMFRs are capable of efficiently burning actinides such as neptunium, americium and curium in addition to all the isotopes of plutonium.[23] Since the vast majority of fission products (isotopes produced by fission reactions) decay rapidly compared to the long-lived actinides (materials produced by neutron capture), the radiological risk factor of fission products sequestered in spent nuclear fuel become less than that of actinides in a period somewhat less than 100 years.[24] The closed LMFBR fuel cycle would produce less than 20% as much transuranic (TRU) waste and 77% as much fission product waste, per megawatt electric (MWe) year, when compared to the open once-through LWR fuel cycle.[25] As a result, LMFRs operating as actinide burners and as marginal breeders combined with uranium, plutonium and minor actinide recovery (reprocessing) were viewed as serving an important nuclear waste reduction and disposal function in a mature closed nuclear fuel cycle.

Although it might seem, from the technical discussion above, that a closed LMFBR fuel cycle has significant technical advantages, there are unresolved and significant proliferation concerns with the closed nuclear fuel cycle and the economics of the LMFBR fuel cycle are not currently competitive with the once-through uranium fuel cycle. Furthermore, there is no shortage of uranium or enrichment services and alternate fuel sources such as coal, petroleum and natural gas are competitive and less controversial sources of energy in the current energy economy. For a further discussion of proliferation concerns, see Section 4.2.2.6.

4.2.2.2 WHY IS FFTF NOT A BREEDER REACTOR?

The FFTF is a LMFR that can operate continuously at 400 MWt at full power. It currently has gas-bonded MOX and HEU oxide fuel designs that, within the limits of those designs, preclude any configuration of the reactor to obtain a breeding ratio above one. In fact, in its standard core configuration, FFTF has a breeding ratio of about 0.40 for MOX fuel and 0.23 for HEU oxide fuel. That these breeding ratios are significantly less than one is an indication that the FFTF was not designed to operate as a breeder reactor.

[21] This follows from the fact that only 0.71% of natural uranium is the fissile isotope U-235 whereas 99.29% of natural uranium is the fertile isotope U-238. As a result, a fuel cycle that is capable of using all significant isotopes of uranium and plutonium as fuel can use as little as ~1% of the heavy metal in its fuel cycle when compared to a fuel cycle that uses only the rare isotope U-235 as fuel.

[22] See typical fuel cycle flow sheets in Benedict, M. et. al., 1981, Nuclear Chemical Engineering, McGraw-Hill, Chapter 7.

[23] The fission/capture cross-section ratios of the TRUs (neptunium, plutonium, americium and curium) are in general significantly more favorable in the fast neutron spectrum, versus the thermal neutron spectrum, for conversion to fission products with short half-lives. Since most commercial power reactors have moderators, their neutron spectra are not sufficiently energetic to efficiently fission large amounts of many of these actinide isotopes. As a result, long-lived TRU isotopes build in and become the primary long-term source of radiotoxicity in spent nuclear fuel from MOX fueled thermal spectra closed fuel cycles.

[24] See *Physics of Plutonium Recycling, Volume I, Issues and Perspectives,* Chapter 4, "Plutonium Recycling and Waste/Radiotoxicity Reduction," NEA, OECD, 1995.

[25] See typical fuel cycle flow sheets in Benedict, M. et. al., 1981, Nuclear Chemical Engineering, McGraw-Hill, Chapter 7. These flow sheets are based on experience with conventional PUREX technology. Future technologies, such as those explored under the cancelled DOE IFR program and the ATW Program might deposit less than 2% of the TRUs as waste when compared to the current U.S. civil fuel cycle.

If the reactor is restarted, the DOE RERTR program will study the feasibility of LEU fuel designs (uranium enrichments less than 20%) consistent with U.S. nonproliferation policy. In either case (HEU or LEU), since a uranium core produces less excess neutrons than a plutonium core, a uranium fuel will always produce a lower breeding ratio than plutonium fuel with comparable fissile content. In short, there is no way that FFTF can be reconfigured using currently existing fuel designs (plutonium or uranium) to achieve a breeding ratio greater than or equal to one. *Therefore, FFTF is not a breeder reactor.*

4.2.2.3 CAN FFTF BE CONVERTED INTO A BREEDER REACTOR?

In order to convert FFTF to operate in a breeding mode, a large engineering study would be required to develop the necessary depleted uranium blanket target designs (radial and axial) and an increase in plutonium density in the driver fuel design would also be required. This increase in density could be achieved by slightly increasing the fraction of plutonium oxide in the MOX fuel or through the use of a Pu-U-Zr ternary sodium-bonded all-metal fuel design such as those considered under the cancelled DOE Integral Fast Reactor (IFR) Program. Since this technology has not been specifically developed with the perspective of converting the FFTF to operate in a breeding mode (this was never part of the FFTF's design mission) this would represent a major new technical program.

Preliminary calculations indicate that, in driver/blanket configurations meant to optimize the breeding ratio, breakeven (breeding ratio nearly equal to one) can be obtained in FFTF using MOX fuel with 24 to 29.5% plutonium oxide content. HEU fuel, regardless of design, cannot achieve a breeding ratio above about 0.80 in the FFTF.[26] All-metal ternary fuel could achieve breakeven with only radial blanket assemblies and could theoretically achieve a breeding ratio as high as 1.20 if axial blankets can be incorporated into the driver fuel design. However, the incorporation of axial blanket technology into the all-metal driver fuel design would likely be technically impossible because of the large axial gas plenum required in that fuel design.

It should be restated that none of the fuel concepts discussed in the above two paragraphs has been developed or considered for use in FFTF and that development of these fuels would involve a lengthy and complex policy, technical and regulatory process. Although breakeven appears to be theoretically possible in FFTF (particularly so for metal fuel), in only one case does it appear theoretically possible to convert the FFTF to a configuration that would operate in a breeding mode and that case would likely not be practically realizable. Furthermore, core configurations that optimize breeding ratio would eliminate all core volume normally available for irradiation services – eliminating the primary mission that FFTF was originally designed to perform. In short, FFTF was not designed to be a breeder reactor but rather, to operate in a burning mode as an irradiation science test bed for the cancelled LMFBR program. Conversion of FFTF to significantly increase its breeding ratio has no rational technical driver and would have significant policy implications.

4.2.2.4 LIKELY POLICY IMPLICATIONS IF FFTF WERE CONVERTED TO OPERATE AS A BREEDER REACTOR

U.S. nonproliferation policy states that "the United States does not encourage the civil use of plutonium and, accordingly, does not itself engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes."[27] The only reason to convert FFTF to operate in a breeding mode would be to

[26] The driver/blanket design (all-metal binary fuel) and core configuration required to maximize the HEU fueled FFTF breeding ratio (up to a theoretical breeding ratio of 0.80) also increases net plutonium production – up to 91kg-Pu/year. Since the net plutonium production only reaches 36kg-Pu/year at the maximum theoretical FFTF breeding ratio of 1.20 (using all-metal ternary fuel), this aptly demonstrates that a uranium fueled reactor operating in a burning mode can significantly out-produce a plutonium fueled breeder reactor. See Appendix 10.4.

[27] See Appendix 10.2

produce more fissile material than it consumes and this would directly imply that the United States intended to recover Pu-239 through reprocessing. Moreover, the only reason to convert the FFTF to optimize plutonium production would also have similar implications. In either case it would be in direct contradiction to the established U.S. policy on plutonium reprocessing.

Under current U.S. reprocessing policy, conversion of FFTF to operate as a breeder reactor or to optimize its plutonium production capability is precluded. Furthermore, conversion of FFTF to operate as a breeder reactor or to optimize plutonium production would require that established U.S. policy be reconsidered to allow for plutonium reprocessing, new fuel would have to be developed, tested and licensed, and a significant NEPA action would be required to assess the environmental impacts of the ensuing reprocessing and fuel fabrication programs. Given these formidable technical, regulatory, and policy obstacles, that FFTF was not originally designed to this intention, and that there are no technical benefits that might be derived through conversion of FFTF, there are no benefits, which could offset the significant costs listed above.

4.2.2.5 DO PLUTONIUM FUELED LMFRS PRODUCE MORE PLUTONIUM THAN COMMERCIAL LWRS?

Given the wide range of operations permitted in LMFRs this question cannot be answered in a general sense. In fact, while LWRs typically produce (net) about 80 g-Pu/MWt-year, LMFRs (depending upon design) can either produce or consume significant amounts of plutonium.[28] The reason is straightforward: since LWRs burn roughly 70% U-235 and 30% in-situ Pu-239 as fuel, they increase net plutonium production in fertile material (U-238) since 70% of the consumed fuel is uranium rather than plutonium.[29] On the other hand, LMFRs consume plutonium as fuel thereby reducing the net production of plutonium. In other words, LMFRs consume large amounts of plutonium fuel, which must be subtracted from the gross plutonium production, giving in general, a much smaller net plutonium production rate than might be expected given the much larger breeding ratio. In the event that a plutonium fueled LMFR is operated below breakeven (as in the FFTF standard MOX configuration), its net plutonium production is less than zero by definition – it destroys plutonium in steady-state operation.

To compare the plutonium production rates of various FFTF configurations and a typical LWR, calculations of plutonium production are shown in Table 4-1 for various theoretical fuel configurations for FFTF and a typical 3000 MWt LWR, scaled down to 400 MWt to simplify comparison.

In plutonium fueled LMFRs the plutonium production rate varies appreciably depending upon reactor design and fuel configuration. Large net plutonium consumption may be achieved as well as significant production depending upon the design limits of the reactor. Uranium fueled reactors, on the other hand, always produce significant amounts of plutonium unless the fuel is very highly enriched so that the fertile material fraction in the fuel is significantly reduced. From the table above, it is clear that, if an optimized breeding configuration is technically achievable, FFTF has a theoretical plutonium production rate comparable to an LWR.[30] On the other hand, the FFTF standard MOX configuration aggressively consumes plutonium and the marginal-breeding configuration produces about half the plutonium of the

[28] Although the Advanced Liquid Metal Reactor (ALMR) design had a technical design requirement to be able to operate as a breeder, it was expected that typical operations would have a breeding ratio between about 0.5 and 1.0. As such, the ALMR would have been able to operate in any mode, maximizing fuel cycle flexibility.

[29] In-situ Pu-239 is plutonium that is both produced and then burned in a given fuel assembly during its tenure in a reactor core. Furthermore, the fission/capture cross-section for U-238 in an LWR is very low, greatly favoring capture, whereas it is much larger in a LMFR such that a certain fraction of U-238 actually directly fissions during LMFR operation.

[30] It is unlikely that the optimized FFTF breeding configuration would be possible to achieve. Technically difficult (or completely impractical) fuel design issues would require creative solutions and the fuel would require extensive development and testing.

two uranium fueled reactor cases shown in the table.[31] Other flowsheet data demonstrate that a full-scale 1000 MWe LMFBR with a breeding ratio of 1.4 produces about 300 kg-Pu/year compared to a 1000 MWe LWR, which produces 250 kg-Pu/year. These are surprisingly comparable net plutonium production figures given that the LMFBR has a breeding ratio nearly 2.5 times larger than a typical LWR.[32]

Table 4-1. Calculation Results Comparing FFTF Configurations to Scaled LWR Plutonium Production[33]

	FFTF Standard Configuration 400 MWt[a]		FFTF Marginal Breeding Configuration 400 MWt[b]	FFTF Optimized Breeding Configuration 400 MWt[c]	Typical LWR scaled to 400 MWt
Fuel Type	MOX U/PuO_2 (~25% PuO_2)	HEU UO_2 (~35% U-235)	Metal U/Pu-10%Zr (~21% Pu)	Metal U/Pu-10%Zr (~21% Pu)	LEU UO_2 (~3.3% U-235)
Breeding Ratio	0.40	0.23	1.03	1.20	0.57
Net Plutonium Gain (kg/yr)	-54	28	17	36	33

[a] The FFTF standard configuration is shown in Appendix 10.4.
[b] This fuel design has not been developed or tested for FFTF. Radial blankets are required but no axial blankets are required.
[c] This fuel design has not been developed or tested for FFTF and would require axial blanket technology that might be technically challenging or impractical. Radial blankets would also be required.

The configuration of FFTF to operate at breakeven with either MOX or ternary metal fuel would also require significant heavy metal flows in the form of depleted uranium blanket material. Preliminary calculations show blanket material flows that are more than three times larger than driver fuel material flows. This implies that operations in this mode would require fuel fabrication capabilities with more than four times the capacity required to produce fuel for the FFTF standard configuration.[34] Furthermore, since all the spent fuel and blankets would require Pu-239 reprocessing in order to receive any benefit from operation in this mode, a significant reprocessing capability is also implied. To operate FFTF in breakeven mode would involve significant technical and financial resources in addition to a complete reversal of U.S. policy on plutonium reprocessing.

It should also be noted that the very high blanket material flows that would be required by FFTF in order to achieve breakeven or breeder operation are not representative of LMFRs that are designed to operate at breakeven or as breeder reactors. In LMFRs designed to have breeding ratios near or above one, blanket material flows are comparable to driver fuel material flows. As such, FFTF operation in this mode is far from economically optimized – a direct indication that the original FFTF design was not intended to be convertible to breeder reactor operation.

The highest production rates of plutonium per megawatt day of exposure occur in specially designed plutonium production reactors that have uranium fuel and targets and either graphite or heavy water moderators. Such plutonium production reactors were designed to supply material for weapons programs at high production rates. Even so, production reactors only achieve breeding ratios below one and are not

[31] A marginal FFTF breeding configuration (near breakeven) would be more achievable than the theoretical optimized breeding configuration, particularly so with ternary metal fuel. Even so, a significant technical program would be required to develop and test the fuel.
[32] See Benedict, M. et. al., 1981, Nuclear Chemical Engineering, McGraw-Hill, Chapter 7.
[33] FFTF data derived from Appendix 10.4. LWR data derived from Benedict, M. et. al., 1981, Nuclear Chemical Engineering, McGraw-Hill, Chapter 7.
[34] This presumes operation at 400 MWt. The FFTF restart alternative proposed to operate at 100 MWt. As a result, operation at breakeven would require 16 times the fuel production capacity than required for the proposed operations.

breeder reactors. It is clear that a breeding ratio above one does not imply a large plutonium production rate. *Given that LMFRs can be designed to aggressively consume plutonium or to produce plutonium whereas LEU fueled reactors always produce plutonium, production capacity is not the primary proliferation concern associated with LMFRs.*

4.2.2.6 FFTF AND LMFR PROLIFERATION CONCERNS

The primary proliferation concern associated with commercial LMFRs is that they require Pu-239 reprocessing in order to achieve the intended commercial benefit regardless of operational mode. To illustrate this point, consider a commercial LMFR that could be operated in any of the three modes: actinide burner, breakeven or breeder. As an actinide burner a LMFR requires, at a minimum, Pu-239 reprocessing of LWR (or other spent fuel) to provide a supply of fuel to optimize actinide consumption during reactor operation. As both breakeven and breeder operations require blanket material flows through the LMFR, this also implies significant additional Pu-239 reprocessing. Furthermore, in the case of breakeven and breeding modes, plutonium driver fuel is generally required since uranium fuel (regardless of enrichment) does not typically produce enough excess neutrons to elevate the breeding ratio up to or above one.

Since typical commercial operation of LMFRs would require Pu-239 reprocessing, the primary proliferation concerns with commercial LMFR operation are identical to the concerns associated with Pu-239 reprocessing.

It is a widely held opinion among nonproliferation and safeguards experts, and is the view of the U.S. Government, that conventional Pu-239 reprocessing techniques (*e.g.*, plutonium uranium redox extraction [PUREX]) is currently a proliferation prone technology. Although reprocessing schemes have been developed that reduce some of the inherent proliferation risks, significant identified concerns still remain regarding the diversion risk that exists in ongoing reprocessing programs in non-nuclear-weapon states.[35] All Pu-239 reprocessing technologies and plutonium fuel fabrication methods developed to date involve complex bulk processing of fissile material. Given that the IAEA defines a significant quantity (SQ) of plutonium to be 8 kg, the margin of error to detect diversion from safeguarded reprocessing programs is very small. Similarly, since the amount of plutonium required to produce a nuclear explosive is very small compared to typical production rates, there is concern that small weapons program could be hidden in the shadows of larger safeguarded civil reprocessing program. In recognition of this threat, the U.S. Government policy is not to "engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes" in order to set an example and to avoid encouraging new starts or expansions of plutonium reprocessing programs in other nations, particularly in regions and nations of proliferation concern.[36]

On a more technical level, there are two additional proliferation concerns commonly associated with LMFRs:

- LMFRs are capable of producing very high quality weapons grade plutonium at relatively high concentrations in fertile blanket material. It is not uncommon to have Pu-239 represent 98% of all

[35] In the past, the DOE IFR program (cancelled in 1994) developed pyroprocessing schemes to recover plutonium in a manner that significantly reduced the theft risk by leaving significant amounts of depleted uranium (~70 atom percent) and fission products in the concentrated plutonium/TRU metal product. As such, the fresh fuel was radiologically self-protecting and its theft risk was significantly reduced when compared to traditional fresh MOX fuel. Unlike traditional aqueous reprocessing, there was no point in the IFR flowsheet where a product stream was a fresh weapons-usable material (such as purified plutonium nitrate in the PUREX flowsheet). Although pyroprocessing was often referred to as being "proliferation resistant" only the theft risk was addressed – diversion risk had not been adequately addressed by the IFR program prior to its cancellation.

[36] See Appendix 10.2

plutonium isotopes in the blanket material and for plutonium concentration to exceed one atom percent heavy metal. The Department and the IAEA do not recognize the difference between various isotopic grades of plutonium when considering safeguards and physical protection measures (except for the case of concentrated Pu-238).[37] Although reactor-grade plutonium can be used to produce nuclear explosives, there is practical value realized from using weapons grade plutonium in nuclear explosives.[38]

- LMFRs, like many research reactor designs, are often very flexible irradiation platforms capable of widely varying modes of operation. This represents an increased safeguards challenge when compared to typical commercial LWR operations. This is particularly the case in non-nuclear-weapon states that have active safeguarded plutonium reprocessing programs.

Finally, an additional concern that has been raised is whether a restarted FFTF might be used at some time in the future to renew development of closed fuel cycles that involve LMFBR technology. Closed fuel cycles are currently excluded by the U.S. policy on reprocessing. Renewed operation of FFTF, which was originally designed to be an irradiation science test bed for the cancelled LMFBR program, might raise questions in the international community about future U.S. intentions toward renewal of LMFBR based closed fuel cycle technology. This might encourage optimism in nations that favor closed fuel cycles that include LMFBRs, inadvertently undermining the U.S. policy on reprocessing.

Nations considering long-term commitments to closed nuclear fuel cycle technologies have in the past been driven primarily by the economics of the energy sector and the need to develop a more secure energy supply. Closed fuel cycle technologies for civil use were boosted during the oil shocks of the 1970's and technology development continued through the early 1990's. The current energy economy does not favor closed fuel cycle technology and closed fuel cycles have proven to be controversial in many nations and have fallen out of favor. These forces are the primary drivers responsible for international interest in closed fuel cycle technology.

Subtle influences such as the renewed operation of FFTF as an irradiation source for missions unrelated to closed fuel cycle are difficult to assess. Whether a restart of FFTF, within the bounds defined by the Draft NI PEIS, would encourage other nations to pursue closed fuel cycles involving LMFBR technology or increase future prospects of a wholesale U.S. reversal on its reprocessing policy is an abstract and subjective analysis. In contrast, this assessment focuses on analysis of the relationship between the missions, facilities, alternatives and options as described in the Draft NI PEIS, and the body of U.S. Government nonproliferation policy, U.S. laws and regulations, and international agreements.

If at some time in the future the U.S. reprocessing policy were reconsidered, there would be without doubt, a contentious public debate. While the Draft NI PEIS does not include any mission description that directly implies that Pu-239 reprocessing activities would be pursued, it does include references to Accelerator Transmutation of Waste (ATW) and advanced reactor concept materials and fuels R&D that might raise concerns about future closed fuel cycle technologies.[39]

The DOE Office of Nuclear Energy has included ATW as one of many possible future civil nuclear energy R&D missions as a placeholder in the event that the U.S. Government decides to pursue this technology. Currently, the Department is performing technical paper studies and planning studies (*e.g.*, the "ATW Road Map") to assist Congress with fiscal and program planning. These efforts are also being

[37] The DOE considers plutonium which is more than 60% Pu-238 to be Attractiveness E (All Other Materials). Similarly, the IAEA exempts plutonium that is more than 80% Pu-238 from safeguards.
[38] DOE Fact Sheet, 1994, *Additional Information Concerning Underground Nuclear Weapon Test of Reactor-Grade Plutonium,* Office of the Press Secretary Washington DC, June 27.
[39] Draft NI PEIS, Chapter 2 and Appendix D

reviewed by the independent Nuclear Energy Advisory Committee (NERAC) Subcommittee on the Accelerator Transmutation of Waste, which in its report of May 23, 2000, recommended that, a study should be launched to identify potential proliferation concerns associated with ATW and possible approaches to mitigate identified concerns. A comprehensive nonproliferation impact assessment of the ATW program plan would be performed by the Office of Arms Control and Nonproliferation prior to proceeding beyond paper studies with actual fuels materials testing in support of ATW (or other technologies that include or imply closed fuel cycle technologies). As such, the nonproliferation impact of a possible future ATW program is not considered in this NI NIA since it is not a well-defined, principal identified mission at this time, but it will be considered in a future nonproliferation impact assessment if the ATW Program moves forward.

4.2.2.7 MITIGATING FACTORS IN A NONPROLIFERATION ASSESSMENT OF FFTF OPERATIONS AS DESCRIBED IN THE DRAFT NI PEIS

There are mitigating factors that relieve proliferation concerns associated with operating FFTF as described in the Draft NI PEIS:

- FFTF will not require Pu-239 reprocessing services in order to operate. All intended plutonium fuel supplies already exist as fresh MOX fuel.
- FFTF spent fuel will not be reprocessed to recover Pu-239.
- FFTF is currently on the list of eligible facilities under the U.S. Voluntary Offer and as such, is subject to selection for international monitoring by the IAEA.
- FFTF will be used in configurations that have breeding ratios significantly less than one and, which do not optimize Pu-239 production.
- Use of existing MOX fuel in FFTF will result in a net reduction in separated stocks of plutonium and will convert significant amounts of fresh MOX fuel into radioactive spent fuel, thereby reducing the theft risk associated with this material.
- LEU fuel will be used in the FFTF, rather than HEU, if this is shown to be technically feasible.
- Use of existing MOX fuel in FFTF would minimize the possible use of HEU oxide fuel in out-year operations if alternative LEU fuel is found to be technically infeasible.
- FFTF will not be used to support defense programs.[40]
- A nonproliferation impact assessment will be written to evaluate the ATW Program prior to use of FFTF as an irradiation services provider in support of fuels materials studies for that program (or other technologies that include or imply closed fuel cycle technologies).

4.2.3 Technical and Policy Factors Analysis

4.2.3.1 TECHNICAL FACTORS

Assuring Against Theft or Diversion. Special nuclear materials and alternate nuclear materials that are required as fuels and targets to perform the FFTF missions described in the Draft NI PEIS are subject to DOE Orders regarding physical protection and material accounting. Continuing implementation of these Orders at the FFTF site (the Hanford MOX fuel is currently under DOE custody at the site) during resumed FFTF operations would maintain the risk of theft at a very low level. Furthermore, since the FFTF is eligible for IAEA monitoring under the U.S. Voluntary Offer, there is sufficient transparency at

[40] This does not imply that medical products developed or produced as a result of FFTF isotope missions could not be used for military medical care.

the FFTF site to assure against diversion of nuclear materials declared excess to defense needs. ● *Fully meets nonproliferation objectives.*

Facilitating Cost-Effective International Monitoring. Since the FFTF and its fuel storage facilities are eligible for IAEA monitoring under the U.S. Voluntary Offer, the IAEA can elect to place the facility, its operations and fissile materials under international safeguards. Furthermore, since reactor operations do not involve complex bulk processing of special fissionable material (SFM) but rather loading and unloading of discrete fuel assemblies, international monitoring can be performed in a cost-effective manner. ● *Fully meets nonproliferation objectives.*

Resulting in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. FFTF operations, as described in the Draft NI PEIS, would result in the irradiation of MOX, HEU or LEU fuel, and neptunium targets. As such, attractive materials such as fresh MOX fuel and fresh neptunium targets would be converted into highly radioactive spent material requiring fully shielded chemical processing to recover nuclear materials. This would have to be followed by other metallurgical processes to bring the materials to forms appropriate for use in nuclear explosives. Prior to irradiation, some processing would also be required to achieve weapons-usable material forms. However, in the absence of fission products and intense radioactivity, the degree of difficulty is significantly reduced. Therefore, FFTF operations result in final material forms (spent fuel and targets) from which retrieval is more difficult than from original material forms. ● *Fully meets nonproliferation objectives.*

4.2.3.2 POLICY FACTORS

Maintaining Consistency with U.S. Nonproliferation Policy. FFTF operations, as described in the Draft NI PEIS, do not require or encourage Pu-239 reprocessing. The use of Hanford MOX as the initial fuel supply is consistent with U.S. policy on the disposition of excess defense plutonium in nuclear reactors.[41] Although the use of imported MOX fuel is unprecedented in this case there are significant mitigating factors that relieve nonproliferation concerns. As such, use of the German MOX is consistent with U.S. nonproliferation policy.[42] If HEU fuel is used in the FFTF in the out-years, it will be in accordance with requirements set forth in the Schumer Amendment and the 1993 Nonproliferation Policy Statement, which requires the Department to technically determine whether LEU fuel is feasible for planned FFTF operations. By scrupulously following these requirements, uranium fuel (either HEU or LEU) can be procured for use in the FFTF in a manner that is consistent with U.S. nonproliferation policy.[43] Within the FFTF mission boundaries, as described in the Draft NI PEIS, FFTF will operate in configurations that preclude operation as a breeder reactor and optimization for the production of Pu-239. Although a possible future ATW R&D mission is mentioned in the Draft NI PEIS as a placeholder, this mission is not central to the proposed FFTF mission and a nonproliferation assessment of ATW is properly the topic of a future programmatic nonproliferation impact assessment. As such, ATW is not considered in this assessment.[44] Finally, the proposed FFTF mission does not include any defense programs. ● *Fully meets nonproliferation objectives.*[45]

Avoiding Encouragement of Plutonium Reprocessing. No Pu-239 reprocessing is involved in FFTF operations. Reprocessing was involved in the fabrication of existing MOX fuel supplies but that fuel is a

[41] See Section 4.2.1.1.
[42] See Section 4.2.1.2.
[43] See Section 4.2.1.3.
[44] See Section 4.2.2.6.
[45] It should be added that operation of the FFTF does not set a precedent that may encourage other states to build new high-flux test reactors using MOX or HEU fuels. The FFTF case is unique: it involves an existing, previously operated facility and the irradiation of previously fabricated MOX fuel now in storage, conditions that are highly unlikely to arise elsewhere. Possible future use of HEU at the facility will be subject to the same strict scrutiny that the United States would wish to have applied by other states considering the use of such fuel.

legacy of past programs that existed prior to the U.S. policy on reprocessing. Both the Hanford and German MOX fuel already exist, and when this identified fuel supply runs out it is proposed, in the Draft NI PEIS, to use uranium fuel rather than to produce additional MOX fuel. Use of the identified MOX fuel at FFTF would not result in any infrastructural expansions, increases in production or in the restart of any reprocessing operations in the United States or in any other country. Thus, the use of the identified MOX fuel would not encourage reprocessing. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. FFTF operations, as described in the Draft NI PEIS, will convert fresh MOX fuel and neptunium targets into highly radioactive spent material. This process will also result in a significant overall reduction in the U.S. inventory, and possibly the German inventory, of separated civil plutonium stocks. As such, the FFTF mission directly reduces stockpiles of weapons-usable nuclear materials, building confidence that the United States is not producing material for nuclear weapons. Furthermore, since the FFTF is eligible for IAEA monitoring under the U.S. Voluntary Offer, the IAEA can elect to place the facility and materials under IAEA safeguards, verifying U.S. assurances. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. The potential impact of future FMCT provisions on reactors and irradiation facilities are not considered in this assessment (see Section 2.1.7). ● *Fully meets nonproliferation objectives.*

4.2.4 Special Considerations for Alternative 1: Restart FFTF

If the Nuclear Infrastructure Record of Decision elects to restart FFTF (under any option), there are some special considerations. To codify the assumptions underlying the conclusion that restart of the FFTF fully meets U.S. nonproliferation policy objectives, the Nuclear Infrastructure Record of Decision should include the following commitments:

- The FFTF will not be configured to operate as a breeder reactor (breeding ratio equal to or greater than one) or to optimize the production of plutonium.
- Spent MOX fuel irradiated in the FFTF will not be reprocessed.
- During the period that the FFTF is fueled with Hanford MOX fuel, an analysis will be undertaken by the RERTR program to determine whether the reactor can be fueled with LEU fuel, and if this is shown to be technically feasible, the reactor will be fueled with LEU fuel following the consumption of existing MOX fuel (Hanford and, possibly, German MOX fuel).
- A nonproliferation impact assessment will be prepared on the ATW program prior to the test irradiation of ATW fuels materials in the FFTF.
- The FFTF will remain available for international monitoring.

4.2.5 Special Case: Technical and Policy Factors Analysis of FFTF Standby and Deactivation

4.2.5.1 TECHNICAL FACTORS

Assuring Against Theft or Diversion. SNM required as fuel to perform the past FFTF missions are subject to DOE Orders regarding physical protection and material accounting. Continuing implementation of these orders at the FFTF site (the Hanford MOX fuel is currently under DOE custody at the site) during FFTF standby/deactivation operations would maintain the risk of theft at a very low level. Furthermore, since the FFTF is eligible for IAEA monitoring under the U.S. Voluntary Offer, there is sufficient transparency at the FFTF site to assure against diversion of nuclear materials. If at some time in the future, the SNM at the FFTF site is disposed of elsewhere, the facility would no longer require material domestic safeguards and would not be subject to the U.S. Voluntary Offer. ● *Fully meets nonproliferation objectives.*

Facilitating Cost-Effective International Monitoring. Since the FFTF and its fuel storage facilities are eligible for IAEA monitoring under the U.S. Voluntary Offer, the IAEA can elect to place the facility, its operations and fissile materials under international safeguards. Furthermore, since reactor operations do not involve complex bulk processing of special fissionable materials but rather accounting for discrete fuel assemblies, international monitoring can be performed in a cost-effective manner. If at some time in the future, the SNM at the FFTF site is disposed of elsewhere, the facility would no longer require material safeguards and security and would not be subject to the U.S. Voluntary Offer. ● *Fully meets nonproliferation objectives.*

Results in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. FFTF standby/deactivation operations would not result in increasing material attractiveness unless the on-site spent fuel storage time period exceeded the lifetime of the radiation barriers of the material. However, since there is fresh MOX fuel at the site, this represents the largest domestic safeguards concern and its attractiveness will not vary appreciably with time unless the fuel is physically altered. If at some time in the future, the SNM at the FFTF site is disposed of elsewhere, the facility would no longer require material safeguards and security and would not be subject to the U.S. Voluntary Offer. ● *Fully meets nonproliferation objectives.*

4.2.5.2 POLICY FACTORS

Maintaining Consistency with U.S. Nonproliferation Policy. FFTF standby/deactivation operations would not require or encourage Pu-239 reprocessing, would not involve the unnecessary civil use HEU, and the facility would remain eligible for international monitoring until SNM are removed from the premises. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. No Pu-239 reprocessing is involved in FFTF standby/deactivation operations. Reprocessing was involved in the fabrication of existing MOX fuel supplies but that fuel is a legacy of past programs that existed prior to the U.S. policy on reprocessing. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. FFTF standby/deactivation operations do not involve material production. If at some time in the future SNM are removed from the facility, they should remain subject to the U.S. Voluntary Offer, building confidence that the United States is not producing material for nuclear weapons. Furthermore, since the FFTF is eligible for IAEA monitoring under the U.S. Voluntary Offer, the IAEA can elect to place the facility and materials under IAEA safeguards while materials are on the premises. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. The potential impact of future FMCT provisions on reactors and irradiation facilities are not considered in this assessment (see Section 2.1.7). ● *Fully meets nonproliferation objectives.*

5 ASSESSMENTS OF OTHER IRRADIATION FACILITIES

5.1 ADVANCED TEST REACTOR

5.1.1 Facility and Mission Description

An expansion of the ongoing missions of the Advanced Test Reactor (ATR) is proposed in Alternative 2, Options 1-3, to support the irradiation requirements for the proposed Pu-238 production mission in the Draft NI PEIS.

The ATR is located at the Idaho National Engineering and Environmental Laboratory (INEEL) in Idaho Falls, Idaho. The ATR began operation in 1967 and was originally designed to study the effects of intense radiation on reactor material samples. It has a maximum power level of 250 megawatts thermal (MWt), uses highly enriched uranium (HEU) oxide aluminum clad plate fuel, is water cooled and moderated, is beryllium reflected, and transfers its primary coolant heat load to secondary coolant through heat exchangers for dissipation to the atmosphere by an induced draft cooling tower. The ATR has nine flux traps in its core and achieves a close integration of flux traps and highly enriched fuel plates by means of a serpentine fuel arrangement.

When viewed from above, the ATR fuel region resembles a four-leaf clover. The flux traps positioned within the four lobes of the reactor core are almost entirely surrounded by fuel, as is the center position. Four other flux trap positions between the lobes have fuel on three sides. This unique design permits large power shifts among the nine flux traps. Also, the ATR is unusual in that it has a solid stainless steel reactor vessel rather than carbon steel clad with stainless steel. Solid stainless steel was chosen to minimize the possibility of brittle fracture after long exposure to intense irradiation. Currently, the ATR runs at a nominal 125 MWt. The positions used for irradiations have a maximum power of approximately 30 MWt. On average, the ATR operates on a 42 day cycle.[1]

ATR provides precise neutron flux levels ranging from 10^{12} neutrons per square centimeter per second (n/[cm^2-s]) in outer holes to 10^{15} n/(cm^2-s) in flux traps for the testing of reactor materials and the production of radioisotopes (Co-60, Ir-191) for medical, industrial, and research applications.

ATR is expected to continue operating for several more decades. The reactor vessel is made of solid stainless steel, and the core internals are replaced every seven to nine years bringing the reactor to an almost new condition. The most recent refit was completed in 1994.

ATR is currently providing irradiation services for the Naval Reactors program, medical and industrial isotope production, and other nuclear research and development (R&D) activities. As such, the Draft NI PEIS proposes to add Pu-238 production to the ATR mission but not additional missions that would simply displace ongoing programs. The planning assumption for ATR is to produce 3 to 5 kilograms (kg) Pu-238 per year. As the program goal is to achieve a production rate of 5 kg per year, either ATR can produce all of the Pu-238 or both ATR and the High Flux Isotope Reactor (HFIR) could be used in conjunction. HFIR and ATR together could meet the program goal of 5 kg per year and could be used in combination with any one of the three processing facilities proposed for the Pu-238 production mission.[2] The proposed target design for Pu-238 production consists of neptunium dioxide blended with aluminum powder, pressed into a target core, and clad with aluminum.

[1] Advanced Test Reactor, http://www.intisoid.com/atr.htm
[2] Draft NI PEIS, Chapter 2

5.1.2 Nonproliferation Assessment

5.1.2.1 RELEVANT NUCLEAR MATERIALS

The ATR uses 93% enriched HEU metallic aluminum clad plate fuel. The ATR fuel is subject to DOE Orders regarding physical protection and material accounting. Under DOE safeguards, the fresh ATR fuel is graded as Category III, Attractiveness Level D (Low-Grade Materials).[3] Following irradiation, ATR HEU fuel is graded as Category IV, Attractiveness Level E (All Other Materials), which is the lowest DOE safeguards grade, as a result of its significant radiological barrier.[4]

Although the ATR currently operates using HEU fuel, it is not in contradiction to U.S. policy on the use of HEU fuel in research and test reactors. The Department's Reduced Enrichment Research and Test Reactor (RERTR) program has plans to conduct a feasibility study of alternate low enriched uranium (LEU) fuel for the ATR in fiscal year 2001. As such, continued operations in the ATR using HEU fuel is consistent with the HEU policy so long as progress is being made toward making a determination and pursuing conversion if technically feasible.[5] Given the very high fissile material density required by ATR operations and missions, the prospect of conversion of the ATR to LEU fuel is not favorable using currently available advanced fuel technology.

Under DOE safeguards, fresh neptunium targets for Pu-238 production are treated as equivalent to material containing an equal concentration of pure U-235. As such, neptunium targets would be treated as Attractiveness Level C (High-Grade Material) under DOE safeguards.[6] The DOE safeguards Category, for material balance areas containing neptunium targets, varies with the mass of neptunium present. The appropriate level of DOE safeguards will be applied to all neptunium operations. Irradiated neptunium targets would be treated in the same manner as spent fuel. That is, if the targets are at or above 100 REM per hour at 1 meter, they would be treated as Category IV, Attractiveness Level E (All Other Materials), and if they are below the spent fuel standard they would be treated either as moderately irradiated material or similar to a fresh target.

5.1.2.2 TECHNICAL AND POLICY FACTORS ANALYSIS

5.1.2.2.1 Technical Factors

Assuring Against Theft or Diversion. Special nuclear material (SNM) and alternate nuclear material (ANM) that are required as fuels and targets to perform the ATR missions described in the Draft NI PEIS are subject to DOE Orders regarding physical protection and material accounting. Continuing implementation of these orders at the ATR facility during expanded ATR operations would maintain the risk of theft at a very low level. Because of current and past defense missions, ATR is excluded from international monitoring. However, since the civil nuclear material under consideration for the described mission is ANM and isotopically concentrated Pu-238, there is no international agreement that provides a basis to install international safeguards to cover the neptunium irradiation mission.[7] ● *Fully meets nonproliferation objectives.*

---

[3] See Appendix 10.1.3, ATR fuel has high enrichment but relatively low uranium density in the matrix, thus it is a Level D material.
[4] See Section 2.2.2
[5] See Appendix 10.1.7.2 and 10.3, Schumer Amendment
[6] See Appendix 10.1.3
[7] Since the ATR has ongoing missions, the marginal proliferation risk added by missions described in the Draft NI PEIS are limited to the risks posed by the neptunium irradiation mission. Ongoing ATR missions are not evaluated in this assessment. See Section 2.1.8 for further relevant discussion on international ANM monitoring.

Facilitating Cost-Effective International Monitoring. Since ATR is permanently excluded from international monitoring for reasons of national security, international monitoring is not possible. However, there is no international agreement that provides a basis to install international safeguards to cover the neptunium irradiation mission in any event. As required by the international agreement on ANM monitoring the U.S. Government will report all ANM exports or export denials thereby satisfying the international monitoring requirements in a cost-effective manner. ● *Fully meets nonproliferation objectives.*

Resulting in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. ATR operations, as described in the Draft NI PEIS, would result in the irradiation of HEU (and possibly LEU) fuel and neptunium targets. As such, attractive materials such as fresh 93% enriched HEU fuel and fresh neptunium targets would be converted into highly radioactive spent material requiring fully shielded chemical processing to recover the nuclear materials. This would have to be followed by other metallurgical processes to bring the materials to forms appropriate for use in nuclear explosives. Prior to irradiation, some processing would also be required to achieve weapons-usable material forms. However, in the absence of fission products and intense radioactivity, the degree of difficulty is significantly reduced. Therefore, ATR operations result in final material forms (spent fuel and targets) from which retrieval is more difficult than from original material forms. ● *Fully meets nonproliferation objectives.*

5.1.2.2.2 Policy Factors

Maintaining Consistency with U.S. Nonproliferation Policy. ATR operations, as described in the Draft NI PEIS, do not require or encourage Pu-239 reprocessing. If HEU fuel continues to be used in the ATR, it will be used in accordance with principles set forth in the Schumer Amendment and the 1993 Nonproliferation Policy Statement, which directs the Department to technically determine whether LEU fuel is feasible for continued ATR operations.[8] By scrupulously following these principles, uranium fuel (either HEU or LEU) can be procured for use in the ATR in a manner that is consistent with U.S. nonproliferation policy. Although the ATR's defense program mission precludes it from international monitoring, there are no U.S. nonproliferation policy directives, international agreements or regulations that generically prevent civil programs from being conducted in current or former defense facilities – ATR is currently hosting civil radioisotope production programs. However, when reasonable alternatives exist that allow civil programs to be hosted in facilities that are eligible for international monitoring, it is preferable to maintain a separation between defense and civil programs. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. No Pu-239 reprocessing is involved or related to ATR operations. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. ATR operations, as described in the Draft NI PEIS, will convert fresh 93% enriched HEU fuel and neptunium targets into highly radioactive spent material. This process will result in a reduction in the U.S. inventory of HEU. As such, an expanded ATR mission directly reduces stockpiles of weapons-usable nuclear material, building confidence that the United States is not producing material for nuclear weapons. Since the ATR is not eligible for international monitoring, there is limited transparency at the facility. However, there is no international agreement that provides a basis to install international safeguards to cover the neptunium irradiation mission. ● *Fully meets nonproliferation objectives.*

[8] See Appendix 10.1.7.2 and 10.3, Schumer Amendment

Supporting Negotiation of a Verifiable FMCT. The potential impact of future FMCT provisions on reactors and irradiation facilities are not considered in this assessment (see Section 2.1.7). ● *Fully meets nonproliferation objectives.*

5.2 HIGH FLUX ISOTOPE REACTOR

5.2.1 Facility and Mission Description

An expansion of the ongoing missions of the High Flux Isotope Reactor (HFIR) is proposed in Alternative 2, Options 7-9, to support the irradiation requirements for the proposed Pu-238 production mission in the Draft NI PEIS.

Since it began full-power operations in 1966, HFIR, at Oak Ridge National Laboratory, has been one of the world's most powerful research reactors. Currently, HFIR's primary mission is neutron-scattering experiments to reveal the structure and dynamics of a very wide range of materials. A secondary mission is the production of Cf-252 and other transuranic (TRU) isotopes for research, industrial, and medical applications. These materials are produced in the flux trap in the center of the HFIR fuel assembly where a working thermal-neutron flux of 2.0 x 10^{15} n/(cm^2-s) is available to irradiate the target material. Additional irradiation facilities are also provided in the beryllium reflector. HFIR also provides for a variety of irradiation tests and experiments that benefit from the high neutron flux available.[9]

HFIR was designed as both a research and isotope production reactor with a maximum thermal neutron flux of 3.0 x 10^{15} n/(cm^2-s) and a full power level of 100 MWt. HFIR uses HEU oxide fuel, is water-cooled and moderated, beryllium-reflected, and transfers its primary coolant heat load to secondary coolant through heat exchangers for dissipation to the atmosphere by an induced-draft cooling tower. The reactor vessel itself is immersed in a pool in a poured-concrete reactor building that also houses the primary coolant pumps and heat exchangers, a spent fuel pool, and experiment areas. The control and water wing of the reactor building contains the reactor control room, relay and amplifier areas, heating and ventilating equipment, pool and fire alarm equipment, instrumentation systems, and office and support rooms. A separate electrical building adjacent to the reactor building contains switch-gear, diesel generators, and associated transformers that connect the facility to offsite power. The reactor building is essentially airtight and provides dynamic confinement. A special building hot exhaust system exhausts air from potentially contaminated areas through two absolute filters (a silver plated copper mesh filter and two charcoal beds) before being released to the atmosphere through a 76 meter (m) stack. The stack serves as the exhaust point for both HFIR and the Radiochemical Engineering Development Center (REDC) at Oak Ridge National Laboratory (ORNL).

After the reactor completed 17.2 full power years of its 20 full power year design life in November 1986, several measures were taken to extend the useful life of the reactor, including de-rating the power level to 85 MWt, adjusting the primary coolant temperature and pressure, conducting annual hydrostatic tests, establishing an irradiation embrittlement surveillance program, and installing an emergency depressurization system.

The reactor vessel has three horizontal beam tubes for neutron beam experiments, experimental facilities located in the beryllium reflector, and, relevant to Pu-238 production, several concentric components on the reactor vertical axis. The innermost component on the core centerline is the target assembly, located within a 12.7 centimeter (cm) diameter hole referred to as a flux trap. The target is surrounded by a large

[9] High Flux Isotope Facility: Introduction, http://www.ornl.gov/hfir/hfir1.html

fuel assembly with two regions, the inner annulus containing 171 fuel plates and the outer annulus containing 369 fuel plates. The control plates, in the form of two thin boron poison-bearing concentric cylinders, are located in the annular region between the outer fuel element and the beryllium reflector.

HFIR is currently providing irradiation services for medical and industrial isotope production, and other nuclear R&D activities. As such, the Draft NI PEIS proposes to add Pu-238 production to the HFIR mission but not additional missions that would simply displace ongoing programs. Under the planning assumptions for Pu-238 production, HFIR could produce from 1 to 2 kg of Pu-238 per year. As the program goal is to achieve a production rate of 5 kg per year, production from both HFIR and ATR would be required to meet this goal. HFIR and ATR together could meet the program goal of 5 kg per year and could be used in combination with any one of the three processing facilities proposed for the Pu-238 production mission.[10] The proposed target design for Pu-238 production consists of neptunium dioxide blended with aluminum powder, pressed into a target core, and clad with aluminum.

5.2.2 Nonproliferation Assessment

5.2.2.1 RELEVANT NUCLEAR MATERIALS

The HFIR uses 93% enriched HEU oxide aluminum clad plate fuel. The HFIR fuel is subject to DOE Orders regarding physical protection and material accounting. Under DOE safeguards, the fresh HFIR fuel is graded as Category III, Attractiveness Level D (Low-Grade Materials).[11] Following irradiation, HFIR HEU fuel is graded as Category IV, Attractiveness Level E (All Other Materials), which is the lowest DOE safeguards grade, as a result of its significant radiological barrier.[12]

Although the HFIR currently operates using HEU fuel, it is not in contradiction to U.S. policy on the use of HEU in research and test reactors. The Department's RERTR program conducted a feasibility study of alternate LEU fuel for the HFIR and presented the results in 1997.[13] The study concluded that currently available high-density plate fuel technology has about half the uranium oxide density that would be required to convert the HFIR to alternate LEU fuel. As such, continued operations in the HFIR using HEU fuel is consistent with the HEU policy so long as R&D continues on higher density plate fuel designs.[14]

Under DOE safeguards, fresh neptunium targets for Pu-238 production are treated as equivalent to material containing an equal concentration of pure U-235. As such, neptunium targets would be treated as Attractiveness Level C (High-Grade Material) under DOE safeguards.[15] The DOE safeguards Category, for material balance areas containing neptunium targets, varies with the mass of neptunium present. The appropriate level of DOE safeguards will be applied to all neptunium operations. Irradiated neptunium targets would be treated in the same manner as spent fuel. That is, if the targets are at or above 100 REM per hour at 1 meter, they would be treated as Category IV, Attractiveness Level E (All Other Materials), and if they are below the spent fuel standard they would be treated either as moderately irradiated material or similar to a fresh target.

---

[10] Draft NI PEIS, Chapter 2
[11] See Appendix 10.1.3, HFIR fuel has high enrichment but relatively low uranium density in the matrix, thus it is a Level D material.
[12] See Section 2.2.2
[13] Mo, S. C. and J. E. Matos, Argonne National Laboratory, *A Neutronic Feasibility Study for LEU Conversion of the High Flux Isotope Reactor (HFIR)*, 1997 International RERTR Meeting, Jackson Hole, WY, October 5-10.
[14] See Appendix 10.1.7.2 and 10.3, Schumer Amendment
[15] See Appendix 10.1.3

5.2.2.2 TECHNICAL AND POLICY FACTORS ANALYSIS

5.2.2.2.1 Technical Factors

Assuring Against Theft or Diversion. SNM and ANM that are required as fuels and targets to perform the HFIR missions described in the Draft NI PEIS are subject to DOE Orders regarding physical protection and material accounting. Continuing implementation of these orders at the HFIR facility during expanded HFIR operations would maintain the risk of theft at a very low level. Furthermore, since the HFIR is eligible for IAEA monitoring under the U.S. Voluntary Offer, there is sufficient transparency at the HFIR facility to assure against diversion of nuclear materials declared excess to defense needs. ● *Fully meets nonproliferation objectives.*

Facilitating Cost-Effective International Monitoring. Since the HFIR and its fuel storage facilities are eligible for IAEA monitoring under the U.S. Voluntary Offer, the IAEA can elect to place the facility, its operations, and fissile materials under international safeguards. Furthermore, since reactor operations do not involve complex bulk processing of special fissionable materials but rather loading and unloading of discrete fuel assemblies, international monitoring can be performed in a cost-effective manner. ● *Fully meets nonproliferation objectives.*

Resulting in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. HFIR operations, as described in the Draft NI PEIS, would result in the irradiation of HEU fuel and neptunium targets. As such, attractive materials, such as fresh 93% enriched HEU fuel and fresh neptunium targets, would be converted into highly radioactive spent materials requiring fully shielded chemical processing to recover the nuclear materials. This would have to be followed by other metallurgical processes to bring the materials to forms appropriate for use in nuclear explosives. Prior to irradiation, some processing would also be required to achieve weapons-usable material forms. However, in the absence of fission products and intense radioactivity, the degree of difficulty is significantly reduced. Therefore, HFIR operations result in final material forms (spent fuel and targets) from which retrieval is more difficult than from original material forms. ● *Fully meets nonproliferation objectives.*

5.2.2.2.2 Policy Factors

Maintaining Consistency with U.S. Nonproliferation Policy. Expanded HFIR operations, as described in the Draft NI PEIS, do not require or encourage Pu-239 reprocessing. HEU fuel is used in the HFIR in accordance with requirements set forth in the Schumer Amendment and the 1993 Nonproliferation Policy Statement, which directed the Department to technically determine whether LEU fuel is feasible for HFIR operations.[16] The RERTR program has conducted a study and determined that HFIR is not convertible to LEU fuel operation using currently available technology. By scrupulously following these principles, HEU fuel can be procured for use in HFIR in a manner that is consistent with U.S. nonproliferation policy. Furthermore, the proposed mission does not include any defense programs and HFIR is eligible for international monitoring under the U.S. Voluntary Offer. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. No Pu-239 reprocessing is involved or related to HFIR operations. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. Expanded HFIR operations, as described in the Draft NI PEIS, will convert fresh 93% enriched HEU fuel and neptunium targets into highly radioactive spent material. As such, an expanded HFIR mission directly

[16] See Appendix 10.1.7.2 and 10.3, Schumer Amendment.

reduces stockpiles of weapons-usable nuclear materials, building confidence that the United States is not producing material for nuclear weapons. Furthermore, since HFIR is eligible for IAEA monitoring under the U.S. Voluntary Offer, the IAEA can elect to place the facility and materials under IAEA safeguards, verifying U.S. assurances. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. The potential impact of future FMCT provisions on reactors and irradiation facilities are not considered in this assessment (see Section 2.1.7). ● *Fully meets nonproliferation objectives.*

5.3 Commercial Light Water Reactor

5.3.1 Facility and Mission Description

An expansion of the ongoing missions of an existing commercial light water reactor (CLWR) is proposed in Alternative 2, Options 4-6, to support the irradiation requirements for the proposed Pu-238 production mission in the Draft NI PEIS.

A typical pressurized CLWR core consists of 170 to 200 fuel assemblies arranged in the reactor vessel in a square lattice that approximates a cylinder. CLWRs operating in the United States are licensed by the NRC to operate at thermal power levels of 2500 to 3800 MWt for net station electrical outputs of 800 to 1300 MWe, generated at about 33% thermodynamic efficiency. CLWRs in the United States use LEU oxide fuel.

The nuclear steam supply system, powered by the pressurized water reactor, is generally arranged as two (or more) heat transport loops, each with two primary coolant circulating pumps and one steam generator in which the primary coolant dissipates heat generated in the reactor core to the secondary working fluid (water) in the steam generator. In addition to serving as a heat transport medium, the primary coolant also serves as both a neutron moderator and reflector and as a solvent for soluble boron (a burnable neutron poison) used as a reactivity control system. The secondary working fluid is then expanded through steam turbines to generate electricity and finally it is condensed and returned through the secondary loop for reuse. The condenser uses cooling water from either an adjacent body of water or from evaporative cooling towers to eliminate about 2000 MWt of waste heat from the power generation process. All nuclear steam supply system components are designed to withstand the effects of earthquakes and loss of coolant accidents.

The containment for a CLWR plant consists of two structures: a steel containment vessel and a reinforced concrete shield building. The containment, including all of its penetrations, is a low leakage steel structure designed to withstand a postulated loss of coolant accident and to confine a postulated release of radioactive material. It houses the reactor pressure vessel, reactor coolant piping, pressurizer, pressurizer quench tank and coolers, reactor primary coolant pumps, steam generators, core flooding tanks, and letdown coolers. Safety systems directly associated with the vessel include the Containment Spray System, the Containment Air Cooling System, and the Containment Isolation System. An annular space is provided between the wall of the containment vessel and the shield building. Overhead clearance from the dome of the shield building is also provided.

The shield building itself is a concrete structure surrounding the containment that is designed to provide biological shielding during both normal operations and hypothetical accident conditions. The shield building enables collection and filtration of fission product leakage from the containment following a hypothetical accident by means of its Emergency Ventilation System. In addition, the shield building provides environmental protection for the containment from adverse atmospheric conditions and external missiles (*e.g.,* acts of sabotage or aircraft accidents).

All fuel assemblies in a CLWR are geometrically identical in mechanical construction and are interchangeable in any core location. The basic fuel assembly is normally composed of 208 to 264 fuel pins (15^2 to 17^2 square arrays), 16 to 24 control rod guide tubes, and one centrally located position for instrumentation. The fuel assembly is approximately 20 to 25 cm on a side, and has an overall length of about 4 m. Each fuel assembly carries on the order of 600 kg of uranium oxide.

Since the primary mission of a CLWR is to produce electricity in an economic manner, the Draft NI PEIS proposes that Pu-238 be produced in a manner that does not conflict with normal CLWR operations (such as the refueling schedule). The requirement for economic operations and high availability, combined with CLWR design preclude flexible production of short-lived medical and industrial isotopes. These products must be produced in reactors that are designed for rapid insertion and removal of targets (not a design quality of pressurized CLWRs). The production planning assumption for the CLWR is 5 kg of Pu-238 per year or 7.5 kg per 18 month operating cycle. Thus, the CLWR alone could meet the program goal of 5 kg per year and could be used in combination with any one of the three proposed processing facilities for the Pu-238 production mission. Targets for a CLWR would be neptunium dioxide blended with aluminum powder, pressed into a target core, clad with either Zircaloy or stainless steel.[17]

5.3.2 Nonproliferation Assessment

5.3.2.1 RELEVANT NUCLEAR MATERIALS

A CLWR uses LEU oxide fuel enriched to slightly above 3%. CLWR fuel is in the custody of U.S. commercial nuclear utilities subject to resident regulatory control by the NRC. As such, it is subject to NRC regulations regarding physical protection and material accounting. Under NRC safeguards, the fresh CLWR fuel is graded as Category III material (special nuclear material of low strategic significance).[18] This is the lowest safeguards grade given by the NRC to special nuclear material. Although this is the lowest safeguards grade, NRC Category III safeguards are still required on fresh LEU fuel. Under NRC safeguards, spent CLWR fuel is graded as Category III material because of its radiological barrier.[19] Under NRC regulations the safeguards grade remains the same as for the fresh fuel because irradiation builds plutonium into the fuel to about 0.9% by oxide weight, the uranium enrichment remains above that of natural uranium and the fuel is already in the lowest safeguards grade. A typical spent CLWR fuel assembly contains 5 to 6 kg of plutonium at full burnup (33,000MW-days per ton).

Under NRC safeguards, fresh neptunium targets for Pu-238 production are not formally categorized. Since no separated ANM is currently subject to NRC regulation, there has been no requirement for the NRC to develop an internal policy concerning ANM safeguards at NRC licensed facilities. However, the NRC is directly involved in the development of international policies and agreements on ANM safeguards and is fully aware of the issues and the DOE safeguards approach to ANM. In the event that a Record of Decision elects to produce Pu-238 in a CLWR, the NRC would publicly issue a Standard Review Plan to formally prescribe an approach to safeguarding ANM at NRC licensed facilities. It is likely that the NRC would follow the DOE lead and treat ANM equivalent to U-235 under the NRC safeguards system. If this turns out to be the case, neptunium targets would be treated as Category I material (formula quantities of strategic special nuclear material) under NRC safeguards. Category I is a much higher level of domestic

[17] Draft NI PEIS, Chapter 2
[18] See Appendix 10.1.4
[19] See Section 2.2.2

safeguards than Category III that is typical of CLWR facilities. NRC would need to increase the level of domestic safeguards at the facility when fresh neptunium targets are present. NRC has currently operating Category I facilities and is very familiar with the domestic safeguards upgrades that would be required.[20] Irradiated neptunium targets would be treated in the same manner as spent fuel. That is, if the targets are at or above 100 REM per hour at 1 meter, they would be treated as Category II material (special nuclear material of moderate strategic significance), and if they are below the spent fuel standard they would be treated as Category I material similar to a fresh target.

5.3.2.2 TECHNICAL AND POLICY FACTORS ANALYSIS

5.3.2.2.1 Technical Factors

Assuring Against Theft or Diversion. SNM and ANM that are required as fuels and targets to perform the CLWR missions described in the Draft NI PEIS are subject to NRC regulations regarding physical protection and material accounting. The presence of fresh neptunium targets would require that domestic safeguards measures at the CLWR be upgraded to the Category I level. Given that these measures were put into place, implementation of these NRC regulations at the CLWR facility would maintain the risk of theft at a very low level. Furthermore, since the CLWR is eligible for IAEA monitoring under the U.S. Voluntary Offer, there is sufficient transparency at the CLWR facility to assure against diversion of nuclear materials. ● *Fully meets nonproliferation objectives.*

Facilitating Cost-Effective International Monitoring. Since the CLWR and its fuel storage facilities are eligible for IAEA monitoring under the U.S. Voluntary Offer, the IAEA can elect to place the facility, its operations and fissile materials under international safeguards. Furthermore, since reactor operations do not involve complex bulk processing of special fissionable materials but rather loading and unloading of discrete fuel assemblies, international monitoring can be performed in a cost-effective manner. ● *Fully meets nonproliferation objectives.*

Resulting in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. Expanded CLWR operations, as described in the Draft NI PEIS, would result in the irradiation of LEU fuel and neptunium targets. Highly attractive fresh neptunium targets would be converted into highly radioactive spent targets requiring fully shielded chemical processing to recover the nuclear material. This would have to be followed by other metallurgical processes to bring the material to forms appropriate for use in nuclear explosives. Prior to irradiation, some processing would also be required to achieve a weapons-usable material form from the neptunium targets. Fresh LEU fuel would not only require chemical processing and conversions but would also require significant enrichment in order to be usable in nuclear explosives. Plutonium built into spent LEU fuel does not increase the attractiveness of that material so long as the radiation barrier remains at or above the spent fuel standard. The attractiveness of spent LEU fuel is unchanged by full burnup irradiation. Therefore, CLWR operations result in final material forms (spent fuel and targets) from which retrieval is more difficult than from original material forms. ● *Fully meets nonproliferation objectives.*

5.3.2.2.2 Policy Factors

Maintaining Consistency with U.S. Nonproliferation Policy. Expanded CLWR operations, as described in the Draft NI PEIS, do not require or encourage Pu-239 reprocessing. LEU fuel is used in the CLWR, the proposed mission does not include any defense programs, and the CLWR is eligible for international monitoring under the U.S. Voluntary Offer. ● *Fully meets nonproliferation objectives.*

[20] For example, the BWX Technologies, Inc. fuel fabrication plant is an NRC Category I facility.

Avoiding Encouragement of Plutonium Reprocessing. No Pu-239 reprocessing is involved or related to expanded CLWR operations. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. Expanded CLWR operations, as described in the Draft NI PEIS, will convert fresh neptunium targets into highly radioactive spent targets. Furthermore, since the CLWR is eligible for IAEA monitoring under the U.S. Voluntary Offer, the IAEA can elect to place the facility and materials under IAEA safeguards. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. The potential impact of future FMCT provisions on reactors and irradiation facilities are not considered in this assessment (see Section 2.1.7). ● *Fully meets nonproliferation objectives.*

5.4 NEW ACCELERATORS

5.4.1 Facility and Mission Description

New accelerators are proposed in Alternative 3, Options 1-3, to support the irradiation requirements of three of the proposed missions in the Draft NI PEIS:

- Medical, industrial and research isotope production.
- Pu-238 production to meet NASA program requirements (minimum production of 5 kg per year).
- Civil nuclear energy R&D.

New Low Energy Accelerator. The planning assumption for the low-energy accelerator is to produce medical and industrial isotopes in conjunction with either the new high-energy accelerator or in combination with Alternative 2 reactor options for Pu-238 production.

The new low-energy accelerator under consideration is a proton-only cyclotron. A new building would be constructed to house the cyclotron and four beam lines. The walls of the facility would be 15 feet thick behind the target stations to minimize the neutron flux outside the building. The walls surrounding the cyclotron itself would be 10 feet thick. The mazes throughout the building would, in general have walls five feet thick so that the total thickness surrounding the cyclotron area would be 10 feet. The beam would be diverted to the four target stations by switching magnets located in the cyclotron vault. The beam would be directed through focusing and steering magnets to the target. In the isotope production beam line (northwest cave) the targets would be installed and removed vertically from a hot cell, which would be located on the second floor directly above the target station. The power supplies for the magnets would be housed with the power supplies for the cyclotron. The mechanical equipment for cooling water would be housed in a shielded mechanical room adjacent to the cyclotron vault. Recirculating water for cooling of the targets and systems that could contain potentially radioactive material would be separated in order to prevent cross contamination. These systems would be contained in mechanical equipment rooms near the respective target station. Piping would be contained in waterproof trenches with leak detection.

The isotope production system would be divided into several sections. There are the beam lines out of the cyclotron, the beam lines into each of the target caves and the target holders and handling system in each of the target caves. There would be three separate target systems set up in this facility. The first would be the radioisotope production system being housed in the northwest target cave. The second would be the positron emission tomography (PET) radioisotope production system housed in the southwest target cave. The third would be the research target system that would be housed in the southeast target cave.[21]

New High-Energy Accelerator. A new high-energy accelerator is proposed to support the requirements of the Pu-238 production mission and to support the civil nuclear energy R&D mission. A new high-energy accelerator in combination with a new low-energy accelerator will support the requirements of the medical, industrial, and research isotope production mission.

In accelerator production of Pu-238, a one billion-electron-volt (1 GeV) proton beam produced by the radio frequency linear accelerator would bombard a depleted uranium (mostly U-238) target, with each proton producing about 40 spallation neutrons. These neutrons would be moderated in a surrounding blanket. The blanket would contain neptunium, which would capture the slowed neutrons to produce Pu-238 through the same nuclear sequence as occurs in a reactor. The accelerator would be housed in a concrete tunnel, buried below ground to provide radiation shielding for operating personnel. A building housing radio frequency power systems and other equipment used to drive, monitor, and control the accelerator would be located above ground close to the accelerator tunnel. The target/blanket assembly would be housed inside a steel and concrete shield located within a multistory building that would contain appropriate service equipment. At the target, the small-diameter proton beam transported magnetically from the accelerator would be converted to a much larger cross section by a beam expander to reduce the power density to acceptable levels for the target cooling systems.

A very preliminary target/blanket design has been developed for scoping purposes, based on the architecture employed in the Accelerator Production of Tritium target/blanket design. It would use 504 kg of depleted uranium, canned in aluminum and cooled and moderated by 11 kg of circulating heavy-water (D_2O), as the neutron-production target. The target would be enclosed by a cup shaped blanket containing 72 kg of neptunium dioxide, canned in aluminum and cooled using circulating light water. Enclosing the target/blanket assembly would be a 2.5 metric ton beryllium reflector.

The planning assumption for the high-energy accelerator is to produce 5 kg Pu-238 per year. A new high-energy accelerator could be used in combination with any one of the three processing facilities proposed for the Pu-238 production mission.[22]

5.4.2 Nonproliferation Assessment

5.4.2.1 RELEVANT NUCLEAR MATERIALS

A new high-energy accelerator would use neptunium targets to produce Pu-238. It is assumed that new facilities described in the Draft NI PEIS would be under the regulatory jurisdiction of DOE. Under DOE safeguards, fresh neptunium targets for Pu-238 production are treated as equivalent to material containing an equal concentration of pure U-235. As such, neptunium targets would likely be treated as Attractiveness Level C (High-Grade Material) under DOE safeguards.[23] The DOE safeguards Category, for material balance areas containing neptunium targets, varies with the mass and concentration of neptunium present. The appropriate level of DOE safeguards will be applied to all neptunium operations. Irradiated neptunium targets would be treated in the same manner as spent fuel. That is, if the targets are at or above 100 REM per hour at 1 meter, they would be treated as Category IV, Attractiveness Level E

[21] Draft NI PEIS, Chapter 2
[22] Ibid.
[23] See Appendix 10.1.3

(All Other Materials), and if they are below the spent fuel standard they would be treated either as moderately irradiated material or similar to a fresh target.

Although 504 kg (~0.5 metric tons) of depleted uranium is used as the spallation target, depleted uranium is not subject to DOE safeguards to prevent proliferation of nuclear weapons (it is not SNM). The IAEA does monitor depleted uranium as source material (SM) but a report is not required unless one "effective kilogram" is present in a facility. One effective kilogram of depleted uranium corresponds to 20 metric tons of actual material since an effective kilogram is based on the enrichment of the material and depleted uranium typically has an enrichment between 0.2% and 0.4% U-235.[24]

Other isotope production targets and products, as defined in the Draft NI PEIS, are not considered SNM and are not subject to DOE safeguards except as required for property protection. Many of the isotopes under consideration for production are extremely radioactive (such as Co-60) and are subject to stringent controls and regulations to protect the health and safety of workers and the general public but these regulations are not associated with proliferation prevention.

Civil nuclear energy R&D materials and fuels that are stored or irradiated at the accelerators would be subject to the same controls and regulations discussed above for Pu-238 production targets. As such, the above discussion is inclusive of these materials. In the event that SNM are irradiated in a new accelerator as part of civil nuclear energy R&D missions, these materials would be subject to DOE Orders on domestic safeguards and the facility would qualify for consideration under the U.S. Voluntary Offer if the amount of SFM reaches or exceeds one effective kilogram.

5.4.2.2 TECHNICAL AND POLICY FACTORS ANALYSIS (NEW LOW-ENERGY ACCELERATOR)

5.4.2.2.1 Technical Factors

Assuring Against Theft or Diversion. SNM and ANM are not required as targets to perform low-energy accelerator missions described in the Draft NI PEIS. As a result, only DOE Orders relevant to safety and property protection at new low-energy accelerator facilities are in force since SNM are not present in reportable quantities. ● *Fully meets nonproliferation objectives.*

Facilitating Cost-Effective International Monitoring. Since a new low-energy accelerator facility would not contain reportable quantities of SNM, there is no basis for international safeguards. Furthermore, ANM would not be present on the site so there are no international ANM monitoring requirement. ● *Fully meets nonproliferation objectives.*

Resulting in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. New low-energy accelerator operations, as described in the Draft NI PEIS, do not require the use of SNM or ANM. ● *Fully meets nonproliferation objectives.*

5.4.2.2.2 Policy Factors

Maintaining Consistency with U.S. Nonproliferation Policy. New low-energy accelerator operations, as described in the Draft NI PEIS, do not require Pu-239 reprocessing or the civil use of HEU. Furthermore, there are no defense missions planned for a new low-energy accelerator. ● *Fully meets nonproliferation objectives.*

[24] See IAEA INFCIRC/288 (US Voluntary Offer), 1981, Article 90, Item G, Definitions of an effective kilogram of material.

Avoiding Encouragement of Plutonium Reprocessing. No Pu-239 reprocessing is required by new low-energy accelerator operations. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. New low-energy accelerator operations, as described in the Draft NI PEIS, will not use or produce reportable quantities of weapons-usable nuclear materials, building confidence that the United States is not producing material for nuclear weapons. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. The potential impact of future FMCT provisions on reactors and irradiation facilities are not considered in this assessment (see Section 2.1.7). ● *Fully meets nonproliferation objectives.*

5.4.2.3 TECHNICAL AND POLICY FACTORS ANALYSIS (NEW HIGH-ENERGY ACCELERATOR)

5.4.2.3.1 Technical Factors

Assuring Against Theft or Diversion. Alternate nuclear materials (ANM) and possibly SNM that are required as targets to perform high-energy accelerator missions described in the Draft NI PEIS would be subject to DOE Orders regarding physical protection and material accounting. Implementation of these Orders at a new high-energy accelerator facility would maintain the risk of theft at a very low level. Only DOE Orders are relevant to domestic safeguards at a new high-energy accelerator facility unless one effective kilogram of special fissionable material (SFM) is present at the facility. If greater quantities of SFM were present at the facility as part of possible civil nuclear energy R&D missions, the facility should be made eligible for international monitoring under the U.S. Voluntary Offer and there would be sufficient transparency at the facility to assure against diversion of nuclear materials. ● *Fully meets nonproliferation objectives.*

Facilitating Cost-Effective International Monitoring. Since a new high-energy accelerator facility would not typically contain one effective kilogram of SFM, there is no basis for international safeguards. In the event that greater quantities of SFM were required for civil nuclear energy R&D missions, the facility should be made eligible for IAEA monitoring under the U.S. Voluntary Offer, the IAEA could elect to place the facility, its operations and fissile materials under international safeguards. As required by the international agreement on ANM monitoring the U.S. Government will report all ANM exports or export denials thereby satisfying the international ANM monitoring requirements. Furthermore, since accelerator operations do not involve complex bulk processing of nuclear material but rather loading and unloading of discrete target assemblies, international monitoring can be performed in a cost-effective manner. ● *Fully meets nonproliferation objectives.*

Resulting in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. New high-energy accelerator operations, as described in the Draft NI PEIS, would result in the irradiation of neptunium targets. Highly attractive fresh neptunium targets would be converted into highly radioactive spent targets requiring fully shielded chemical processing to recover the nuclear material. This would have to be followed by other metallurgical processes to bring the material to a form appropriate for use in nuclear explosives. In the event that nuclear fuels are irradiated in this facility, the attractiveness of those materials would also be reduced. Therefore, new high-energy accelerator operations would result in final material forms from which retrieval is more difficult than from original material forms. ● *Fully meets nonproliferation objectives.*

5.4.2.3.2 Policy Factors

Maintaining Consistency with U.S. Nonproliferation Policy. New high-energy accelerator operations, as described in the Draft NI PEIS, do not require Pu-239 reprocessing or use HEU. A new high-energy accelerator should be made eligible for international monitoring if sufficient quantities of SFM are present. Although a possible future ATW R&D mission is mentioned in the Draft NI PEIS as a placeholder, this mission is not central to the proposed new high-energy accelerator mission and a nonproliferation assessment of ATW is properly the topic of a future programmatic nonproliferation impact assessment. As such, ATW is not considered in this assessment.[25] Finally, the proposed new high-energy accelerator mission does not include any defense programs. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. No Pu-239 reprocessing is required by new high-energy accelerator operations. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. New high-energy accelerator operations, as described in the Draft NI PEIS, will convert fresh neptunium targets into highly radioactive spent targets. This operation does not produce material for nuclear weapons. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. The potential impact of future FMCT provisions on reactors and irradiation facilities are not considered in this assessment (see Section 2.1.7). ● *Fully meets nonproliferation objectives.*

5.5 NEW RESEARCH REACTOR

5.5.1 Facility and Mission Description

A new research reactor is proposed in Alternative 4, Options 1-3, to support the irradiation requirements of three of the proposed missions in the Draft NI PEIS:

- Medical, industrial and research isotope production.
- Pu-238 production to meet NASA program requirements (minimum production of 5 kg per year).
- Civil nuclear energy R&D.

Operating at 50 MWt, the core of the new research reactor would require an active cooling system with forced coolant flow to maintain the fuel below its thermal limits. New research reactor cooling system design would likely use a tank within a pool, connected to primary coolant circulating pumps, heat exchangers, with reactor heat ultimately discharged to cooling towers. The pool would be housed in a reactor building that would also enclose the pumps, heat exchangers, secondary systems, and spent nuclear fuel storage pool. The spent fuel storage pool would be sized to store the reactor core's discharged spent fuel for its entire 35-year lifetime. This pool can be hydraulically connected to the reactor core pool for refueling operations and emergency reflooding of the reactor core. The cooling towers, air exhaust stack, and emergency diesel generators would be located outside the reactor building.

New research reactor core design might consist of 68 fuel assemblies, each of which is enclosed in a square aluminum shroud for structural support and coolant flow control. The core design might also

[25] See Section 1.6.8

include eight rabbit tubes (pneumatic transport) for short irradiation-time production of medical or industrial radioisotopes and nuclear R&D projects. These rabbit tubes would be located outside the fuel region of the core, but still within an area with relatively high neutron flux.

LEU TRIGA (training, research, isotopes, General Atomics) fuel would be used in the new research reactor core. TRIGA fuel has been used in research reactors since 1958 with over 50 TRIGA reactors currently operating worldwide at licensed steady-state power levels of 0.02 to 16 MWt and power pulsing capabilities of up to 22,000 MWt. This fuel design has demonstrated ability to provide high burnup cladding integrity as well as reliable performance. The new research reactor fuel design would be an extension to current LEU TRIGA fuel for higher power reactor cores except that the new research reactor fuel would have a larger assembly configuration array (8 by 8 versus 4 by 4) and a longer active fuel length (153.7 cm versus 55.88 cm).

The planning assumption for new research reactor is to produce 5 kg Pu-238 per year. New research reactor could be used in combination with any one of the three processing facilities proposed for the Pu-238 production mission. In addition, new research reactor could produce all of the proposed isotope products and provide irradiation services for civil nuclear energy R&D programs.[26] The new research reactor neptunium target design is aluminum clad neptunium dioxide.

5.5.2 Nonproliferation Assessment

5.5.2.1 RELEVANT NUCLEAR MATERIALS

New research reactor would use LEU oxide TRIGA fuel enriched to slightly below 20%. It is presumed in this assessment that new facilities (including new research reactor), performing the missions described in the Draft NI PEIS, would be under the regulatory jurisdiction of DOE. As such, it would be subject to DOE Orders regarding physical protection and material accounting. Under DOE safeguards, the fresh TRIGA fuel would be graded as Category IV, Attractiveness Level E (All Other Materials).[27] This is the lowest safeguards grade given by the Department to SNM. Although this is the lowest safeguards grade, DOE Category IV safeguards are still required for fresh LEU fuel. Under DOE safeguards, spent TRIGA fuel attractiveness is unchanged and is graded as Category IV, Attractiveness Level E (All Other Materials).

Under DOE safeguards, fresh neptunium targets for Pu-238 production are treated as equivalent to material containing an equal concentration of pure U-235. As such, neptunium targets would be treated as Attractiveness Level C (High-Grade Material) under DOE safeguards.[28] The DOE safeguards Category, for material balance areas containing neptunium targets, varies with the mass of neptunium present. The appropriate level of DOE safeguards will be applied to all neptunium operations. Irradiated neptunium targets would be treated in the same manner as spent fuel. That is, if the targets are at or above 100 REM per hour at 1 meter, they would be treated as Category IV, Attractiveness Level E (All Other Materials), and if they are below the spent fuel standard they would be treated either as moderately irradiated material or similar to a fresh target.

Other isotope production targets and products, as defined in the Draft NI PEIS, are not considered special nuclear material and are not subject to DOE safeguards except as required for property protection. Many of the isotopes under consideration for production are extremely radioactive (such as Co-60) and are

[26] Draft NI PEIS, Chapter 2
[27] See Appendix 10.1.3
[28] Ibid.

subject to stringent controls and regulations to protect the health and safety of workers and the general public but these regulations are not associated with proliferation prevention.

Civil nuclear energy R&D materials and fuels that are stored or irradiated at the new research reactor would be subject to the same controls and regulations discussed above for nuclear fuels and isotope targets. As such, the above discussion is inclusive of these materials.

5.5.2.2 TECHNICAL AND POLICY FACTORS ANALYSIS

5.5.2.2.1 Technical Factors

Assuring Against Theft or Diversion. SNM and ANM that are required as fuels and targets to perform new research reactor missions described in the Draft NI PEIS would be subject to DOE Orders regarding physical protection and material accounting. Implementation of these Orders at the new research reactor facility would maintain the risk of theft at a very low level. Furthermore, since new civil program research reactor should be made eligible for IAEA monitoring under the U.S. Voluntary Offer, there would be sufficient transparency to assure against diversion of nuclear materials. ● *Fully meets nonproliferation objectives.*

Facilitate Cost-Effective International Monitoring. Since the new research reactor and its fuel storage facility should be made eligible for IAEA monitoring under the U.S. Voluntary Offer, the IAEA can elect to place the facility, its operations and fissile materials under international safeguards. Furthermore, since reactor operations do not involve complex bulk processing of SFM but rather loading and unloading of discrete fuel assemblies, international monitoring can be performed in a cost-effective manner. ● *Fully meets nonproliferation objectives.*

Results in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. New research reactor operations, as described in the Draft NI PEIS, would result in the irradiation of LEU fuel and neptunium targets. Highly attractive fresh neptunium targets would be converted into highly radioactive spent targets requiring fully shielded chemical processing to recover the nuclear materials. This would have to be followed by other metallurgical processes to bring the materials to forms appropriate for use in nuclear explosives. Prior to irradiation, some processing would also be required to recover weapons-usable material from the neptunium targets. Fresh LEU fuel would not only require chemical processing and conversions but would also require enrichment in order to be usable in nuclear explosives. Plutonium built into spent LEU fuel does not increase the attractiveness of that material so long as the radiation barrier remains at or above the spent fuel standard. Therefore, new research reactor operations would result in final material forms (spent fuel and targets) from which retrieval is as or more difficult than from original material forms. ● *Fully meets nonproliferation objectives.*

5.5.2.2.2 Policy Factors

Maintaining Consistency with U.S. Nonproliferation Policy. New research reactor operations, as described in the Draft NI PEIS, do not require or encourage Pu-239 reprocessing. LEU fuel would be used in a new research reactor, the proposed mission does not include any defense programs, and a new research reactor should be made eligible for international monitoring. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. No Pu-239 reprocessing is involved or related to new research reactor operations. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. New research reactor operations, as described in the Draft NI PEIS, will convert fresh neptunium targets into highly radioactive spent targets. Furthermore, since a new research reactor would be eligible for IAEA monitoring under the U.S. Voluntary Offer, the IAEA can elect to place the facility and materials under IAEA safeguards. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. The potential impact of future FMCT provisions on reactors and irradiation facilities are not considered in this assessment (see Section 2.1.7). ● *Fully meets nonproliferation objectives.*

6 ASSESSMENTS OF TARGET FABRICATION AND PROCESSING FACILITIES

6.1 RADIOCHEMICAL ENGINEERING DEVELOPMENT CENTER

6.1.1 Facility and Mission Description

An expansion of the ongoing missions of the Radiochemical Engineering Development Center (REDC) is proposed in various options under Alternatives 1 through 4 to support the chemical processing requirements for the proposed Pu-238 production mission in the Draft NI PEIS. In each case, REDC is paired with an irradiation facility to produce 5 kilograms (kg) of Pu-238 per year. In addition, under the No Action Alternative, Option 2, REDC is proposed as a long-term storage site for the separated neptunium inventory.

REDC consists of buildings 7920, 7930, and associated support facilities at the Oak Ridge National Laboratory (ORNL). REDC is the production, storage, and distribution center for the DOE heavy-element research program. REDC and the neighboring High Flux Isotope Reactor (HFIR) were built to produce quantities of transuranic (TRU) elements for use in research. Operations for both facilities were begun in 1966. Since then, REDC has been the main center of production for TRU elements in the United States.[1]

REDC building 7930 is divided into four major areas: 1) a cell complex with seven cells, six shielded and one unshielded, 2) maintenance and service areas surrounding the cell complex, 3) an operating control area, and 4) an office area adjacent to, but isolated from, the operating areas. Included also are utility services, ventilation systems, crane and manipulator systems, and liquid-waste systems.

The proposed Pu-238 processing and storage activities would require equipment installation in three main areas of the second floor of REDC Building 7930. The activities required for preparing the neptunium oxide, mixing it with aluminum, and preparing the mixture for either pellet fabrication or extrusion would take place in shielded gloveboxes. The mechanical operations involved in the final target fabrication may present lesser hazards that permit them to be carried out in open boxes.

Cell E would contain processing equipment to purify the separated Pu-238 product, prepare the Pu-238 oxide, and transfer the oxide into shipping containers. Cell E would also contain vertical storage wells for dry storage of neptunium and other actinides.

Cell D activities would include receipt of irradiated targets, target dissolution, chemical separation of neptunium and Pu-238 from fission products, and partitioning and purification of neptunium and Pu-238. Cell D would also contain process equipment to remove TRU elements from the aqueous waste streams and to solidify the TRU waste.[2]

6.1.2 Nonproliferation Assessment

6.1.2.1 RELEVANT NUCLEAR MATERIALS

For the Pu-238 production mission, REDC would receive and process neptunium oxide from the Savannah River Site (SRS) into fresh neptunium targets, irradiated neptunium targets would be received

[1] Radiological Engineering Development Center, http://redc.ct.ornl.gov/
[2] Draft NI PEIS, Chapter 2

from an irradiation facility and processed to recover and purify Pu-238 and neptunium. Recovered neptunium would be recycled to produce additional fresh targets. Under DOE safeguards, neptunium for Pu-238 production is treated as equivalent to material containing an equal concentration of pure U-235. As such, the inventory of fresh and purified neptunium oxide or concentrated solution will be used to determine the category and attractiveness levels under DOE safeguards.[3] If a decision is made to use REDC as a long-term storage facility for the U.S. inventory of separated neptunium oxide, that material would be subject to the same level of safeguards as fresh neptunium materials unless the protactinium gamma dose should rise to or above the level of 15 REM per hour at 1 meter. Radioactive neptunium materials would be treated in accordance with their radiological barrier. That is, if the materials are at or above 100 REM per hour at 1 meter, they would be treated as Category IV, Attractiveness Level E (All Other Materials) and if they are below that level they would be treated as either a moderately radioactive material or similar to fresh material.

Although material that contains plutonium that is greater than 60% Pu-238 is treated as Attractiveness Level E (All Other Materials) this material is rigorously protected against loss, theft and sabotage (through physical protection and accounting) and is strictly contained (to prevent accidental release) as a result of the health and safety risks presented by the material. Under DOE safeguards, Pu-238 is reportable in 0.1 gram quantities.

6.1.2.2 TECHNICAL AND POLICY FACTORS ANALYSIS

6.1.2.2.1 Technical Factors

Assuring Against Theft or Diversion. There is currently no DOE plan or intention to use REDC to process or store special nuclear material (SNM) other than isotopically concentrated Pu-238 as part of the mission described in the NI PEIS. Use of REDC to store Category I, Attractiveness Level C, neptunium and process highly attractive neptunium material will require the DOE to upgrade the facilities domestic safeguards systems. DOE has significant experience safeguarding Category I nuclear facilities. Use of the REDC to process neptunium target materials would involve complex bulk processing, separation, and purification of ANM. This makes implementation of material accounting more difficult. Even so, DOE has significant experience with material accounting for conventional aqueous processing and target fabrication equipment. Given that a REDC Pu-238 processing line would be new equipment that has never been used or contaminated, high-quality material accounting and monitoring systems could be incorporated prior to installation and operation in the hot cell and glovebox environments. Application of DOE physical protection and material accounting procedures would reduce the risk of theft to a low level.

Since the materials in question are not special fissionable materials (SFM), there is no basis or need to include REDC on the eligible list for U.S. civil facilities under the U.S. Voluntary Offer.[4] As a nuclear-weapon state, the United States is obligated under the international ANM monitoring agreement to report exports and export denials of ANM. Any export or export denial of ANM associated with a REDC Pu-238 production mission would be reported as required by the international agreement.[5] ● *Fully meets nonproliferation objectives.*

Facilitating Cost-Effective International Monitoring. As a nuclear-weapon state, the United States is obligated under the international ANM monitoring agreement to report exports and export denials of ANM. Any export or export denial of ANM associated with a REDC Pu-238 production mission would

[3] See Appendix 10.1.3
[4] See Section 2.1.5
[5] See Section 2.1.8

be reported as required by the international agreement. Since recovery of Pu-238 from neptunium targets involves chemical processes comparable to traditional Pu-239 reprocessing, it is possible that REDC would be captured under a future FMCT international monitoring regime. Since the Building 7930 hot cell facility proposed for the REDC Pu-238 production mission has no national security missions and could be made available for international monitoring, sufficient transparency could be provided if the facility were captured by an FMCT. If Building 7930 is selected to produce Pu-238, a U.S. commitment to reserve the facility for civil nuclear programs would mitigate any concerns about future international monitoring access. ● *Fully meets nonproliferation objectives.*

Resulting in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. The recovery of Pu-238 from neptunium targets involves chemical processes that separate and purify neptunium and Pu-238 from irradiated target material. As such, ANM is recovered and purified (put into a more retrievable form) for further irradiation. However, each time targets are processed, the total U.S. inventory of neptunium is reduced by the amount of the production rate of Pu-238 plus waste product isotopes such that the inventory of neptunium is significantly reduced over repeated Pu-238 production cycles. On the other hand, even though the total neptunium inventory is reduced, irradiated neptunium is processed and neptunium is put into a final material form that is easier to retrieve for use in a nuclear explosive. Overall, the balance of these competing outcomes raises *significant uncertainty* since high-grade materials are produced. ◑ *Might raise nonproliferation concerns.*

6.1.2.2.2 Policy Factors

Maintaining Consistency with U.S. Nonproliferation Policy. Because REDC would not separate Pu-239, require unnecessary civil use of highly enriched uranium (HEU), or infringe on existing international agreements, use of this facility for the purpose described by the Draft NI PEIS is consistent with U.S. nonproliferation policy. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. Production of Pu-238 from neptunium targets involves chemical processes that are comparable to traditional Pu-239 reprocessing (albeit on a very small scale). However, Pu-238 production does not separate Pu-239 and therefore does not constitute "plutonium reprocessing" as the term is understood in existing U.S. nonproliferation policy. However, because of the similarity of the processes, the Department should issue a clear statement that the facilities used to produce Pu-238 will not be used to perform Pu-239 reprocessing. Since REDC has never been used for large-scale production of defense SNM, U.S. assurances would mitigate any nonproliferation concern. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. Although the production of Pu-238 from neptunium targets involves the repeated separation and purification of ANM, it also results in a significant overall reduction in the U.S. inventory of separated neptunium. As such, the Pu-238 production mission directly reduces the stockpile of ANM, building confidence that the United States is not producing material for nuclear weapons. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. Since the processes intended for the REDC Pu-238 production mission might be captured under a FMCT because of their similarity to Pu-239 reprocessing, it is essential that programs be implemented in the REDC in such a manner as to allow potential future international monitoring under a FMCT. Since the Building 7930 hot cell facility proposed for the REDC Pu-238 production mission has no national security missions and could be made available for international monitoring, sufficient transparency could be provided if the facility were captured by an

FMCT. If Building 7930 is selected to produce Pu-238, a U.S. commitment to reserve the facility for civil nuclear programs would mitigate any concerns about future international monitoring access. ● *Fully meets nonproliferation objectives.*

6.1.2.3 NEPTUNIUM STORAGE: TECHNICAL AND POLICY FACTORS ANALYSIS

6.1.2.3.1 Technical Factors

Assuring Against Theft or Diversion. Use of REDC to store Category I, Attractiveness Level C neptunium oxide will require the DOE to upgrade the facilities domestic safeguards systems. Even so, DOE has significant experience safeguarding Category I nuclear facilities. Application of DOE physical protection and material accounting procedures would reduce the risk of theft to a very low level.

Since the materials in question are not SFM, there is no basis or need to include REDC on the eligible list for U.S. civil facilities under the U.S. Voluntary Offer. As a nuclear-weapon state, the United States is obligated under the international ANM monitoring agreement to report exports and export denials of ANM. Any export or export denial of ANM associated with a REDC storage mission would be reported as required by the international agreement. ● *Fully meets nonproliferation objectives.*

Facilitating Cost-Effective International Monitoring. As a nuclear-weapon state, the United States is obligated under the international ANM monitoring agreement to report exports and export denials of ANM. Any export or export denial of ANM associated with a REDC storage mission would be reported as required by the international agreement thereby facilitating cost-effective international monitoring. ● *Fully meets nonproliferation objectives.*

Resulting in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. The storage of neptunium in REDC does not result in changes in material forms. However, the level of radioactive daughters (protactinium) that grow into neptunium over time will increase its radiation barrier. ● *Fully meets nonproliferation objectives.*

6.1.2.3.2 Policy Factors

Maintaining Consistency with U.S. Nonproliferation Policy. Because REDC would not separate Pu-239, require unnecessary civil use of HEU, or infringe on existing international agreements, use of this facility for neptunium storage as described by the Draft NI PEIS is consistent with U.S. nonproliferation policy. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. REDC would not separate Pu-239 as part of a neptunium storage mission. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. REDC would not produce material for nuclear weapons as part of a neptunium storage mission. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. REDC would not be captured as a result of a neptunium storage mission. Since REDC has significant hot cell facilities, it may be captured for this reason but that possibility is unaffected by a neptunium storage mission. ● *Fully meets nonproliferation objectives.*

6.2 FLUORINEL DISSOLUTION PROCESS FACILITY

6.2.1 Facility and Mission Description

The Fluorinel Dissolution Process Facility (FDPF) is proposed in various options under Alternatives 1 through 4 to support the chemical processing requirements for the proposed Pu-238 production mission in the Draft NI PEIS. In each case, FDPF is paired with an irradiation facility to produce 5 kg of Pu-238 per year. In addition, under the No Action Alternative, Option 3, the related storage facility, CPP-651, is proposed as a long-term storage site for the separated neptunium inventory.

FDPF is located at the Idaho Nuclear Technology and Engineering Center (INTEC), which is located northeast of the Central Facilities Area at the Idaho National Engineering and Environmental Laboratory (INEEL) and approximately 2 miles southeast of the Advanced Test Reactor (ATR). Historically, INTEC reprocessed spent fuel from U.S. Navy reactors to recover reusable HEU. After DOE announced in April 1992 that it would no longer reprocess spent fuel because of the Nation's declining need for HEU, INTEC reprocessing operations ended.

Two buildings at INTEC are proposed storage and processing sites for Pu-238 production: Building CPP-651, the Unirradiated Fuel Storage Facility, and Building CPP-666, the Fluorinel Dissolution Process/Fuel Storage Facility (FDPF).

Building CPP-651 was originally designed for the storage of special nuclear materials to support Defense Programs and is quite flexible in terms of the size and shape of special nuclear materials that it can receive and store. The 100 storage positions in the vault use the existing structural barriers of Building CPP-651 (earth and concrete) and provide supplemental security protection via their in-ground concrete storage silo design. Each storage position houses a rack that can hold seven nuclear material canisters. Racks are raised and lowered in their storage positions via and overhead one-ton hoist. Building CPP-651 does not have the capability to repackage neptunium oxide and is not designed to unload highly radioactive materials from large shield casks.

Building CPP-666 is divided into two parts, the Fuel Storage Facility and FDPF. The Fuel Storage Facility consists or receiving and unloading areas, a fuel unloading pool, and six storage pools for storing nuclear fuel.

FDPF was designed and built to process Navy fuel via three dissolver trains. When fuel reprocessing was discontinued, uranium and hazardous materials were flushed from FDPF and the facility is currently under consideration for new missions. FDPF consists of a large hot cell and supporting areas with a total area of approximately 40,000 square feet. The facility is divided into five levels identified by their elevation relative to ground level.

The FDPF cell is approximately 20 feet wide, 100 feet long and 50 feet deep with 6 foot-thick concrete walls. The cell includes manipulators, three dissolvers, off-gas cleanup systems, complexing vessels, process makeup vessels, pumps, valves, piping and instrumenation. The interim storage rack area located in the south end of the cell could be used to store irradiated targets. The proposed continuous 12.5 liter or batch 200 liter dissolution vessel would be located in proximity to the existing train, plumbed to faciliate use of the existing dissolver off-gas system. The chemical separation of Pu-238, neptunium and waste products would take place in the FDPF cell using small centrifugal contactors installed for that purpose. Four separate transfer lines connect the FDPF hot cell with Building CPP-601, which can transfer the waste to CPP-604, where the wastes would be concentrated in evaporators.

Neptunium oxide would be stored in CPP-651 vault. There are 100 in-ground concrete-shielded storage well positions in the vault. Each storage well contains a rack that can be modified to house cans of neptunium.

6.2.2 Nonproliferation Assessment

6.2.2.1 RELEVANT NUCLEAR MATERIALS

For the Pu-238 production mission, FDPF would receive and process neptunium oxide from SRS into fresh neptunium targets, irradiated neptunium targets would be received from an irradiation facility and processed to recover and purify Pu-238 and neptunium. Recovered neptunium would be recycled to produce additional fresh targets. Under DOE safeguards, neptunium for Pu-238 production is treated as equivalent to material containing an equal concentration of pure U-235. As such, the inventory of fresh and purified neptunium oxide or concentrated solution will be used to determine the category and attractiveness levels under DOE safeguards.[6] If a decision is made to use CPP-651 as a long-term storage facility for the U.S. inventory of separated neptunium oxide, that material would be subject to the same level of safeguards as fresh neptunium materials unless the protactinium gamma dose should rise to or above the level of 15 REM per hour at 1 meter. Radioactive neptunium materials would be treated in accordance with their radiological barrier. That is, if the materials are at or above 100 REM per hour at 1 meter, they would be treated as Category IV, Attractiveness Level E (All Other Materials) and if they are below that level they would be treated as either a moderately radioactive material or similar to fresh material.

Although material that contains plutonium that is greater than 60% Pu-238 is treated as Attractiveness Level E (All Other Materials) this material is rigorously protected against loss, theft and sabotage (through physical protection and accounting) and is strictly contained (to prevent accidental release) as a result of the health and safety risks presented by the material. Under DOE safeguards, Pu-238 is reportable in 0.1 gram quantities.

6.2.2.2 TECHNICAL AND POLICY FACTORS ANALYSIS (FDPF)

6.2.2.2.1 Technical Factors

Assuring Against Theft or Diversion. There is currently no DOE plan or intention to use FDPF or CPP-651 to process or store SNM other than isotopically concentrated Pu-238 as part of the mission described in the NI PEIS. However, the FDPF is co-located with a spent fuel storage pond that currently contains U.S. Navy SNM. CPP-651 also contains related SNM. Use of the FDPF to process neptunium targets would involve complex bulk processing, separation and purification of ANM. This makes implementation of material accounting more difficult. Even so, DOE has significant experience with material accounting for conventional aqueous processing and target fabrication equipment, and high-quality domestic safeguards systems are currently installed and operational at both facilities. Given that a FDPF Pu-238 processing line would be new equipment that has never been used or contaminated, high-quality material accounting and monitoring systems could be incorporated prior to installation and operation in the contaminated process cell and glovebox environments. Continued application of DOE physical protection and material accounting procedures would maintain the risk of theft at a low level.

[6] See Appendix 10.1.3

Since the materials in question are not SFM, there is no basis or need to include FDPF on the eligible list for U.S. civil facilities under the U.S. Voluntary Offer.[7] As a nuclear-weapon state, the United States is obligated under the international ANM monitoring agreement to report exports and export denials of ANM. Any export or export denial of ANM associated with a FDPF Pu-238 production mission would be reported as required by the international agreement.[8] ● *Fully meets nonproliferation objectives.*

Facilitating Cost-Effective International Monitoring. As a nuclear-weapon state, the United States is obligated under the international ANM monitoring agreement to report exports and export denials of ANM. Any export or export denial of ANM associated with a FDPF Pu-238 production mission would be reported as required by the international agreement. Since recovery of Pu-238 from neptunium targets involves chemical processes comparable to traditional Pu-239 reprocessing, it is possible that FDPF could be captured under a future FMCT international monitoring regime. Since FDPF and CPP-651 are currently excluded from international monitoring for reasons of national security, cost effective international monitoring is currently not possible, raising a *significant identified concern.* ○ *Raises nonproliferation concerns.*

Resulting in Final Material Forms from which Retrieval is More Difficult than from Original Material Forms. The recovery of Pu-238 from neptunium targets involves chemical processes that separate and purify neptunium and Pu-238 from irradiated target material. As such, an alternate nuclear material is recovered and purified (put into a more retrievable form) for further irradiation. However, each time targets are processed, the total U.S. inventory of neptunium is reduced by the amount of the production rate of Pu-238 plus waste product isotopes such that the inventory of neptunium is significantly reduced over repeated Pu-238 production cycles. On the other hand, even though the total neptunium inventory is reduced, irradiated neptunium is processed and neptunium is put into a final material form that is easier to retrieve for use in a nuclear explosive. Overall, the balance of these competing outcomes raises *significant uncertainty* since high-grade materials are produced. ◑ *Might raise nonproliferation concerns.*

6.2.2.2.2 Policy Factors

Maintaining Consistency with U.S. Nonproliferation Policy. Because the FDPF and CPP-651 would not separate Pu-239, require unnecessary civil use of HEU, or infringe on currently existing international agreements, use of this facility for the purpose described by the NI PEIS is consistent with U.S. nonproliferation policy. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. Production of Pu-238 from neptunium targets involves chemical processes that are comparable to traditional Pu-239 reprocessing. However, Pu-238 production does not separate Pu-239 and therefore does not constitute “plutonium reprocessing” as the term is understood in existing U.S. nonproliferation policy. Because of the similarity of the processes, the Department should issue a clear statement that the facilities used to produce Pu-238 will not be used to perform Pu-239 reprocessing. Since FDPF is a former defense reprocessing facility (for HEU recovery) and is currently excluded from international monitoring for reasons of national security, international monitoring is currently not possible and U.S. assurances regarding reprocessing cannot be verified. As such, renewed activity (for other than health or safety reasons) in FDPF might create *significant uncertainty* in the international community regarding the U.S. commitment to the U.S. reprocessing policy, regardless of U.S. assurances. ◑ *Might raise nonproliferation concerns.*

[7] See Section 2.1.5
[8] See Section 2.1.8

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. Although the production of Pu-238 from neptunium targets involves the repeated separation and purification of ANM, it also results in a significant overall reduction in the U.S. inventory of separated neptunium. As such, the Pu-238 production mission directly reduces the stockpile of ANM, building confidence that the United States is not producing material for nuclear weapons. However, since FDPF is a former defense reprocessing facility and is currently excluded from international monitoring for reasons of national security, international monitoring is currently not possible and U.S. assurances regarding weapons material production cannot be verified – possibly raising *significant uncertainty* in the international community. ◑ *Might raise nonproliferation concerns.*

Supporting Negotiation of a Verifiable FMCT. Since the processes intended for the FDPF Pu-238 production mission might be captured under a FMCT because of their similarity to Pu-239 reprocessing, it is essential that programs be implemented in the FDPF in such a manner as to allow potential future international monitoring under a FMCT. Since FDPF is currently excluded from international monitoring for reasons of national security, international monitoring is currently not possible. Since Draft NI PEIS proposed civil activities would be pursued concurrent with Navy nuclear propulsion programs in the same facilities, and the civil activities would not qualify for an exemption under an FMCT; difficulties might arise in clarification of the FDPF's status under an FMCT raising a *significant identified concern*. ○ *Raises nonproliferation concerns.*

6.2.2.3 NEPTUNIUM STORAGE : TECHNICAL AND POLICY FACTORS ANALYSIS (CPP-651)

6.2.2.3.1 Technical Factors

Assuring Against Theft or Diversion. Using CPP-651 to store Category I, Attractiveness Level C neptunium oxide would not require DOE to upgrade the facilities domestic safeguards systems (CPP-651 is currently a Category I facility). Application of DOE physical protection and material accounting procedures would reduce the risk of theft to a very low level.

Since the materials in question are not SNM, there is no basis or need to include CPP-651 on the eligible list for U.S. civil facilities under the U.S. Voluntary Offer. There is Navy program SNM currently stored in CPP-651 but this is defense material and not subject to the U.S. Voluntary Offer. As a nuclear-weapon state, the United States is obligated under the international ANM monitoring agreement to report exports and export denials of ANM. Any export or export denial of ANM associated with a CPP-651 storage mission would be reported as required by the international agreement. ● *Fully meets nonproliferation objectives.*

Facilitating Cost-Effective International Monitoring. As a nuclear-weapon state, the United States is obligated under the international ANM monitoring agreement to report exports and export denials of ANM. Any export or export denial of ANM associated with a CPP-651 storage mission would be reported as required by the international agreement thereby facilitating cost-effective international monitoring. ● *Fully meets nonproliferation objectives.*

Resulting in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. The storage of neptunium in CPP-651 does not result in changes in material forms. However, the level of radioactive daughters (protactinium) that grow into neptunium over time will increase its radiation barrier resulting eventually in a less attractive material. ● *Fully meets nonproliferation objectives.*

6.2.2.3.2 Policy Factors

Maintaining Consistency with U.S. Nonproliferation Policy. Because CPP-651 would not separate Pu-239, require unnecessary civil use of HEU, or infringe on existing international agreements, use of this facility for neptunium storage as described by the Draft NI PEIS is consistent with U.S. nonproliferation policy. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. CPP-651 would not separate Pu-239 as part of a neptunium storage mission. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. CPP-651 would not produce material for nuclear weapons as part of a neptunium storage mission. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. CPP-651 would not be captured as a result of a neptunium storage mission. ● *Fully meets nonproliferation objectives.*

6.3 FUELS AND MATERIALS EXAMINATION FACILITY

6.3.1 Facility and Mission Description

The Fuels and Materials Examination Facility (FMEF) is proposed in various options under Alternatives 1 through 4 to support the chemical processing requirements for the proposed Pu-238 production mission in the Draft NI PEIS. In each case, FMEF is paired with an irradiation facility to produce 5 kg of Pu-238 per year. In addition, under Alternative 1, Options 3 and 6 FMEF is proposed for medical and industrial isotope target fabrication and isotope recovery missions and civil nuclear R&D missions. Furthermore, under the No Action Alternative, Option 4, FMEF is proposed as a long-term storage site for the separated neptunium inventory.

FMEF is in the 400 Area on the Hanford Site near Richland, Washington. Constructed in the early 1980s, it has never been used. It was constructed to support the U.S. Liquid Metal Fast Breeder Reactor (LMFBR) program, and was designed specifically to manufacture mixed oxide (MOX) fuel and to manipulate (disassemble and inspect) irradiated fuel assemblies.

FMEF’s current mission is to maintain the facility in a condition suitable for future missions. The FMEF building is clean and uncontaminated because no nuclear materials have been introduced, and the facility is in excellent condition to perform future missions if needed.[9]

FMEF consists of the process building, which has an attached mechanical equipment wing on the west side and an entry wing provides space for the reactor fuel assembly, lunchroom, change rooms, security station, office space, and administrative support areas. The process building is 175 feet wide by 270 feet long and extends from 35 feet below grade to 98 feet above grade. Total operating space is approximately 188,000 square feet. The building is divided into six operating floors, or levels, which are identified by their distance from ground level. The process building contains several large interconnected hot cells and many smaller connected hot cells. Large cranes are available, but some cranes, windows, and manipulators were not installed because construction was halted prior to completing work on the hot cell complex.

[9] See http://www.hanford.gov/eis/fmef_fs.htm

FMEF has the physical attributes required to process, handle, and store large quantities of SNM. It has a massive, reinforced concrete, hardened structure with safety related equipment and systems designed to withstand the Hanford design-basis earthquake, tornado, high winds, and volcanic ash fall events. FMEF was also designed to meet the physical domestic safeguards requirements for processing and storing Category I SNM.

Ample space exists in FMEF for Pu-238 production support, and numerous facility configurations are possible. The process support would be located on the 35-foot level and would utilize the process support cells to house the irradiated target processing equipment. The configuration would also contain this project within as few levels as possible. Alternative facility configurations are also possible.

There is a shipping and receiving bay located on the 0-foot level that would be used to support the shipment and receipt of safe secure trailers (SSTs) and irradiated target cask transporters. Additional facilities on this level would be used to transfer irradiated targets into the storage area, decontaminate and prepare equipment for maintenance, and package remote-handled solid waste for disposal. On the 17-foot level, the entry tunnel transporter would be utilized along with the existing facility systems as needed.

The 35-foot level would house most of the processing and storage functions for Pu-238 production. Neptunium storage and target fabrication and assembly would be located in rooms on the south side of this level.

The south bank of the process support cells would be dedicated to target processing. Located on the 35-foot level, the 14 process support cells are arranged in two parallel rows along a horizontal transfer corridor. The process support cell complex is approximately 40 feet wide by 99 feet long. With the exception of Cell 146, each of the process support cells is 14 feet high and is lined with stainless steel. Cell 146 extends to the 0-foot level and would be lined with stainless steel for the proposed mission. The process support cell area is heavily shielded with either 48 inches or 32 inches of high-density concrete. Work in the cells would be performed using remotely operated equipment.

Irradiated neptunium targets would be lowered through a hatch into Cell 147 and would be stored awaiting processing. Target processing would begin in Cell 146 and would proceed through Pu-238 oxide conversion, storage, and loadout in Cell 142. The main target processing activities would occur in Cell 146. Existing wastewater collection systems would be used, and hot repair facilities would be available on this level.[10]

6.3.2 Nonproliferation Assessment

6.3.2.1 RELEVANT NUCLEAR MATERIALS

For the Pu-238 production mission, FMEF would receive and process neptunium oxide from SRS into fresh neptunium targets, irradiated neptunium targets would be received from an irradiation facility and processed to recover and purify Pu-238 and neptunium. Recovered neptunium would be recycled to produce additional fresh targets. Under DOE safeguards, neptunium for Pu-238 production is treated as equivalent to material containing an equal concentration of pure U-235. As such, the inventory of fresh and purified neptunium oxide or concentrated solution will be used to determine the category and attractiveness levels under DOE safeguards.[11] If a decision is made to use FMEF as a long-term storage

[10] Draft NI PEIS, Chapter 2
[11] See Appendix 10.1.3

facility for the U.S. inventory of separated neptunium oxide, that material would be subject to the same level of safeguards as fresh neptunium materials unless the protactinium gamma dose should rise to or above the level of 15 REM per hour at 1 meter. Radioactive neptunium materials would be treated in accordance with their radiological barrier. That is, if the materials are at or above 100 REM per hour at 1 meter, they would be treated as Category IV, Attractiveness Level E (All Other Materials) and if they are below that level they would be treated as either a moderately radioactive material or similar to fresh material.

Although material that contains plutonium that is greater than 60% Pu-238 is treated as Attractiveness Level E (All Other Materials) this material is rigorously protected against loss, theft and sabotage (through physical protection and accounting) and is strictly contained (to prevent accidental release) as a result of the health and safety risks presented by the material. Under DOE safeguards, Pu-238 is reportable in 0.1 gram quantities.

Other isotope production targets and products, as defined in the Draft NI PEIS, are not considered SNM and are not subject to DOE safeguards except as required for property protection. Many of the isotopes under consideration for production are extremely radioactive (*e.g.,* Co-60) and are subject to stringent controls and regulations to protect the health and safety of workers and the general public but these regulations are not associated with proliferation prevention.

Civil nuclear energy R&D materials and fuels that are stored or processed at FMEF would be subject to the same controls and regulations discussed above for nuclear materials. As such, the above discussion is inclusive of these materials.

6.3.2.2 TECHNICAL AND POLICY FACTORS ANALYSIS

6.3.2.2.1 Technical Factors

Assuring Against Theft or Diversion. FMEF will be used to process and store SNM and ANM as part of the missions described in the Draft NI PEIS. Use of the FMEF to store and process neptunium targets would involve complex bulk processing, separation and purification of ANM. Although this makes implementation of material accounting more difficult, given that the FMEF has never been used or contaminated and that DOE has significant experience with material accounting for conventional aqueous processing and target fabrication equipment, high quality material accounting systems could be installed. Application of DOE physical protection and material accounting procedures would reduce the risk of theft to a low level.

Since the materials immediately in question are not SFM, there is no current basis or need to include FMEF on the eligible list for U.S. civil facilities under the U.S. Voluntary Offer.[12] As a nuclear-weapon state, the United States is obligated under the international ANM monitoring agreement to report exports and export denials of ANM. Any export or export denial of ANM associated with a FMEF Pu-238 production mission would be reported as required by the international agreement.[13] In the event that civil nuclear energy R&D missions require that more than one effective kilogram of SFM be stored or handled in FMEF, the facility should be made eligible under the U.S. Voluntary Offer. Sufficient transparency exists to mitigate diversion concerns. ● *Fully meets nonproliferation objectives.*

[12] While the materials specifically defined in the Draft NI PEIS are not SFM, civil nuclear R&D materials may, in the future, include greater than one effective kilogram of SFM. See Section 1.6.8.
[13] See Section 2.1.8

Facilitating Cost-Effective International Monitoring. As a nuclear-weapon state, the United States is obligated under the international ANM monitoring agreement to report exports and export denials of ANM. Any export or export denial of ANM associated with a REDC Pu-238 production mission would be reported as required by the international agreement. Since recovery of Pu-238 from neptunium targets involves chemical processes comparable to traditional Pu-239 reprocessing, it is possible that FMEF could be captured under a future FMCT international monitoring regime. Since FMEF has never been used there is no reason that it could not be made available for international monitoring under an FMCT. If FMEF is selected to produce Pu-238, a U.S. commitment to reserve the facility for civil nuclear programs would mitigate any concerns about future international monitoring access. Furthermore, in the event that civil nuclear energy R&D missions require that more than one effective kilogram of SFM be stored or handled in FMEF, the facility should be made eligible under the U.S. Voluntary Offer, facilitating cost-effective international monitoring. ● *Fully meets nonproliferation objectives.*

Resulting in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. The recovery of Pu-238 from neptunium targets involves chemical processes that separate and purify neptunium and Pu-238 from irradiated target material. As such, ANM is recovered and purified (put into a more retrievable form) for further irradiation. However, each time targets are processed, the total U.S. inventory of neptunium is reduced by the amount of the production rate of Pu-238 plus waste product isotopes such that the inventory of neptunium is significantly reduced over repeated Pu-238 production cycles. On the other hand, even though the total neptunium inventory is reduced, irradiated neptunium is processed and neptunium is put into a final material form that is easier to retrieve for use in a nuclear explosive. Overall, the balance of these competing outcomes raises *significant uncertainty* since high-grade materials are produced. ◑ *Might raise nonproliferation concerns.*

6.3.2.2.2 Policy Factors

Maintaining Consistency with U.S. Nonproliferation Policy. Because the FMEF would not separate Pu-239, require unnecessary civil use of HEU, or infringe on existing international agreements, use of this facility for the purpose described by the Draft NI PEIS is consistent with U.S. nonproliferation policy. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. Production of Pu-238 from neptunium targets involves chemical processes that are comparable to traditional Pu-239 reprocessing (albeit on a very small scale). However, Pu-238 production does not separate Pu-239 and therefore does not constitute “plutonium reprocessing” as the term is understood in existing U.S. nonproliferation policy. However, because of the similarity of the processes, the Department should issue a clear statement that the facilities used to produce Pu-238 will not be used to perform Pu-239 reprocessing. Since FMEF has never been used and should be available under the U.S. Voluntary offer if sufficient quantities of SFM are present, U.S. assurances would mitigate any nonproliferation concern. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. Although the production of Pu-238 from neptunium targets involves the repeated separation and purification of ANM, it also results in a significant overall reduction in the U.S. inventory of separated neptunium. As such, the Pu-238 production mission directly reduces the stockpile of ANM, building confidence that the United States is not producing material for nuclear weapons. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. Since the processes intended for the FMEF Pu-238 production mission might be captured under a FMCT because of their similarity to Pu-239 reprocessing, it is essential that programs be implemented in the FMEF in such manner as to allow potential future international monitoring under an FMCT. If FMEF is selected to produce Pu-238, a U.S. commitment to reserve the facility for civil nuclear programs would mitigate any concerns about future international monitoring access. ● *Fully meets nonproliferation objectives.*

6.3.2.3 NEPTUNIUM STORAGE: TECHNICAL AND POLICY FACTORS ANALYSIS

6.3.2.3.1 Technical Factors

Assuring Against Theft or Diversion. Use of FMEF to store Category I, Attractiveness Level C neptunium oxide would require the DOE to upgrade the facility's domestic safeguards systems. Even so, DOE has significant experience safeguarding Category I nuclear facilities. FMEF was originally engineered to be a Category I facility, but was never completed or operated. Application of DOE physical protection and material accounting procedures would reduce the risk of theft to a very low level.

Since the materials in question are not SFM, there is no basis or need to include FMEF on the eligible list for U.S. civil facilities under the U.S. Voluntary Offer. As a nuclear-weapon state, the United States is obligated under the international ANM monitoring agreement to report exports and export denials of ANM. Any export or export denial of ANM associated with a FMEF storage mission would be reported as required by the international agreement. ● *Fully meets nonproliferation objectives.*

Facilitating Cost-Effective International Monitoring. As a nuclear-weapon state, the United States is obligated under the international ANM monitoring agreement to report exports and export denials of ANM. Any export or export denial of ANM associated with a FMEF storage mission would be reported as required by the international agreement thereby facilitating cost-effective international monitoring. ● *Fully meets nonproliferation objectives.*

Resulting in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. The storage of neptunium in FMEF does not result in changes in material forms. However, the level of radioactive daughters (protactinium) that grow into neptunium over time will increase its radiation barrier resulting eventually in a less attractive material. ● *Fully meets nonproliferation objectives.*

6.3.2.3.2 Policy Factors

Maintaining Consistency with U.S. Nonproliferation Policy. Because FMEF would not separate Pu-239, require unnecessary civil use of HEU, or infringe on existing international agreements, use of this facility for neptunium storage as described by the Draft NI PEIS is consistent with U.S. nonproliferation policy. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. FMEF would not separate Pu-239 as part of a neptunium storage mission. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. FMEF would not produce material for nuclear weapons as part of a neptunium storage mission. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. FMEF would not be captured as a result of a neptunium storage mission. Since FMEF has significant hot cell facilities, it may be captured for this reason but that possibility is unaffected by a neptunium storage mission. ● *Fully meets nonproliferation objectives.*

6.4 HANFORD 300 AREA FACILITIES

6.4.1 Facility and Mission Description

Under Alternative 1, Options 1, 2, 4 and 5, two Hanford 300 Area facilities are proposed to support the medical and industrial isotope target fabrication and processing and civil nuclear R&D missions: the Radiochemical Processing Laboratory (RPL), Building 325, and the Development Fabrication Test Laboratory, Building 306-E.

RPL houses R&D activities of the Radiochemical Processing Group in the Hanford 300 Area. RPL consists of a central area that contains general-purpose laboratories designed for lower-level radioactive work (hoods and glove boxes), a front wing that contains office space and shops, and two annexes that provide hot cell facilities for high-level radioactive work. The facility also contains laboratories and specialized facilities designed for work with nonradioactive materials, microgram to kilogram quantities of fissile materials, and up to megacurie quantities of radionuclides. The RPL would be the primary site for fabricating radioactive targets (*e.g.,* targets containing radium-226) and processing irradiated targets and recovering radioactive isotope products.

Total space within the RPL is 143,700 square feet, of which 44,500 square feet are occupied by general chemistry laboratories. A recent space utilization survey of the RPL indicated that 6,950 square feet, representing 15.6% of the facility, are presently unoccupied. All of the occupied and nearly all of the unoccupied laboratories are functional and are fully equipped with standard utilities. Several of the laboratories, especially those used for radioanalytical work, have been renovated during the past few years. Upgrading and modernization of the equipment within the chemistry laboratories has been given a high priority during the past two years.

During the space utilization survey at the RPL, an assessment was made of the number of fume hoods and shielded glove boxes (including several small hot cells) that are available in the chemistry laboratories for additional programmatic work. Of the 79 functional fume hoods and 23 shielded glove boxes, 50 fume hoods and 15 glove boxes are available for additional work.

A special feature of the RPL is the existence of two heavily shielded hot cell facilities located in annexes on the east and west sides of the building. These shielded facilities are the High-Level Radiochemistry Facility and the Shielded Analytical Laboratory. These two hot cell complexes are heavily used because they provide capabilities for conducting bench-scale to pilot-scale work with a wide variety of highly radioactive materials. Their capabilities include those required to conduct radiochemical separation and purification procedures, irradiated fuel or target sectioning and processing, metallography, physical properties testing of activated metals, thermal processing (including waste vitrification), and radioanalytical and preparatory chemistry operations.

The High-Level Radiochemistry Facility contains three large, interconnected hot cells designated as A-Cell, B-Cell and C-Cell. Each of the three cells is 15 feet high and 7 feet deep. The A-Cell is 15 feet wide, and the B-Cell and C-Cell are each 6 feet wide. In-cell operations are performed using medium-duty electromechanical manipulators, and operators view their work through leaded-glass, oil-filled windows. Closed-circuit television cameras and videocassette recorders have been installed for detailed inspection work within the hot cells. The A-Cell and G-Cell also have overhead bridges that contain hoists with a 2,200 kg capacity. The hot cells are fully equipped with utilities and have shielded service penetrations at the front wall to allow insertion of special instruments. Each hot cell contains several process vessels located below the work deck that range in capacity from 4 to 320 liters. A large shielded door and a shielded double-door transfer port located in the rear wall of the cell provide access to each hot cell in the High-Level Radiochemistry Facility. Cask payloads weighing up to 2,200 kg can be transferred into and out of the hot cells using a bridge crane located in the canyon behind the cells.

The Shielded Analytical Laboratory contains six interconnecting hot cells, each of which is 5.5 feet wide, 5.5 feet deep, and 9.5 feet high. Each hot cell is equipped with a pair of medium-duty manipulators. Turntables built into the rear walls of the hot cells provide rapid transfers of radioactive samples into and out of the cells. The Shielded Analytical Laboratory hot cells are equipped to perform a wide variety of analytical chemistry operations with highly radioactive samples.

The primary features and functions of the laboratories within RPL that would be used for processing targets irradiated at FFTF are described below:

- A cluster of 10 laboratories would be available on the first floor of the RPL. Each laboratory would contain a small hot cell, a shielded glove box and a fume hood with interconnecting transfer ports.
- A transfer port for receiving casks containing irradiated targets into the A-Cell of the High-Level Radiochemistry Facility would be installed, and provision would be made in the G-Cell for initial processing of highly radioactive targets (*e.g.*, irradiated europium targets containing Gd-153).
- Target preparation and storage areas would be provided in the basement of the RPL, in close proximity to the facilities where the radioactive and recycled targets would be assembled and welded.

A 1,500 square foot laboratory equipped with a radon gas capture system would be available in the basement of the RPL to process radium-226 targets and the product isotopes generated by irradiation of these targets (all of these targets generate radon gas as intermediate products in their decay chains).

306-E is located in the north-central portion of the Hanford 300 Area and has been used historically to fabricate a variety of reactor components, fuel assemblies, and isotope target assemblies. Some of the equipment, including nondestructive examination equipment, is still in the building. Based on a preliminary engineering evaluation, a conceptual design plan has been developed for the utilization of 306-E to fabricate nonradioactive isotope targets and gas tag capsules. These targets would be subjected to nondestructive examination and placed in secure storage areas within 306-E before shipment to FFTF for irradiation.

6.4.2 Nonproliferation Assessment

6.4.2.1 RELEVANT NUCLEAR MATERIALS

Medical and industrial isotope production targets and products, as defined in the Draft NI PEIS, are not considered SNM and are not subject to DOE safeguards except as required for property protection. Many of the isotopes under consideration for production are extremely radioactive (*e.g.*, Co-60) and are subject to stringent controls and regulations to protect the health and safety of workers and the general public but these regulations are not associated with proliferation prevention.

Civil nuclear energy R&D materials and fuels that are stored or processed at RPL or 306-E would be subject to the same controls and regulations discussed above for other isotope targets. As such, the above discussion is inclusive of these materials.

6.4.2.2 TECHNICAL AND POLICY FACTORS ANALYSIS

6.4.2.2.1 Technical Factors (RPL)

Assuring Against Theft or Diversion. Although there is no defined plan for RPL to process or store SNM as part of the missions described in the Draft NI PEIS, such an eventuality might arise in a future civil nuclear R&D mission. RPL does have current inventories of SNM associated with other unrelated programs and these programs are currently subject to DOE physical protection and material accounting procedures that reduce the risk of theft to a low level. The Draft NI PEIS mission description for RPL does not currently describe materials of diversion concern. Furthermore, RPL is on the eligibility list for the U.S. Voluntary Offer and is available for international monitoring. ● *Fully meets nonproliferation objectives.*

Facilitating Cost-Effective International Monitoring. RPL is on the eligibility list for the U.S. Voluntary Offer and is available for international monitoring. ● *Fully meets nonproliferation objectives.*

Resulting in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. RPL is not being considered under the Draft NI PEIS for a mission involving separations of SNM or ANM. ● *Fully meets nonproliferation objectives.*

6.4.2.2.2 Policy Factors (RPL)

Maintaining Consistency with U.S. Nonproliferation Policy. Because the RPL would not separate Pu-239, require unnecessary civil use of HEU, or infringe on existing international agreements, use of this facility for the purpose described by the Draft NI PEIS is consistent with U.S. nonproliferation policy. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. The mission described for RPL in the Draft NI PEIS does not include any activity that would encourage plutonium reprocessing. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. The mission described for RPL in the Draft NI PEIS does not include any activity that would produce fissile material potentially useful for nuclear explosives. Furthermore, the RPL is on the eligibility list for the U.S. Voluntary Offer and is available for international monitoring. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. The mission described for RPL in the Draft NI PEIS does not include any activity that should be captured under an FMCT. In the event that RPL is captured because of some similarity to plutonium reprocessing (operating hot cells, etc.), the RPL is on the eligibility list for the U.S. Voluntary Offer and is available for international monitoring. ● *Fully meets nonproliferation objectives.*

6.4.2.2.3 Technical Factors (306-E)

Assuring Against Theft or Diversion. Although there is no defined plan for 306-E to process or store SNM as part of the missions described in the Draft NI PEIS, such an eventuality might arise in a future civil nuclear R&D mission. At this time 306-E does not have an inventory of nuclear materials subject to application of DOE physical protection and material accounting procedures and as such, there are no nuclear materials of diversion concern. If 306-E is ever used to store or fabricate SNM containing targets, the facility should be made eligible for the U.S. Voluntary Offer. ● *Fully meets nonproliferation objectives.*

Facilitating Cost-Effective International Monitoring. 306-E is not being considered under the Draft NI PEIS for a mission involving SNM or ANM. As such, there is no need for international monitoring. However, if 306-E is ever used to store or fabricate SNM containing targets, the facility should be made eligible for the U.S. Voluntary Offer. ● *Fully meets nonproliferation objectives.*

Results in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. 306-E is not being considered under the Draft NI PEIS for a mission involving SNM or ANM. Furthermore, this facility is a former fuel/target fabrication facility and does not change the attractiveness of nuclear materials. ● *Fully meets nonproliferation objectives.*

6.4.2.2.4 Policy Factors (306-E)

Maintaining Consistency with U.S. Nonproliferation Policy. Because 306-E would not separate Pu-239, require unnecessary civil use of HEU, or infringe on existing international agreements, use of this facility for the purpose described by the Draft NI PEIS is consistent with U.S. nonproliferation policy. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. The mission described for 306-E in the Draft NI PEIS does not include any activity that would encourage plutonium reprocessing. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. The mission described for 306-E in the Draft NI PEIS does not include any activity that would produce fissile material potentially useful for nuclear explosives. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. The mission described for 306-E in the Draft NI PEIS does not include any activity that could be captured under an FMCT. ● *Fully meets nonproliferation objectives.*

6.5 NEW SUPPORT FACILITY

6.5.1 Facility and Mission Description

A new support facility is proposed in Alternatives 3 and 4 (all options) to support the medical and industrial isotope production and civil nuclear energy R&D missions when the proposed irradiation facility is either the new low-energy accelerator or the new research reactor. Although this facility would support the civil nuclear R&D mission, the Draft NI PEIS specifically excludes fissile materials from its mission.

The new support facility is located at an undefined generic DOE site in the same general vicinity (0.2 to 5 miles) as a new irradiation facility (research reactor or low-energy accelerator). Collocation with the irradiation facility would be needed to process some irradiated target materials promptly after removal from the reactor or accelerator and would minimize transportation risks. Although the facility could be located within the irradiation facility security protection area, the lack of a defense mission and the lack of SNM and ANM presence in the new support facility indicate that a high level of physical protection may not be warranted.

The new support facility mission would be accommodated by a one-story above-grade building with a basement area under a portion of the footprint. The facility is designed around a center area containing the highest-risk activities and the material inventories requiring the highest levels of engineered controls. Irradiated materials in casks or other shielded transport containers would enter a loading dock with a straight-line access to the primary facility hot cell. The hot sample entry area would be a high bay area with a high floor loading area between the loading dock and the hot cell access port. This configuration would allow transport cask access to the hot cell. In addition, an overhead hoist would be available to facilitate handling of materials and devices in the proximity of the hot cell.

The hot cell would accept high radiation level samples or those difficult to shield or manipulate (*e.g.*, reactor core components containing samples). The hot cell would have access to a conveyor that can remotely transport samples to the hot process laboratories. In addition, samples from the hot cell could be transferred to the hot R&D laboratory glove boxes for detailed analysis and testing. Hot cell manipulators would be located on both the operating gallery and the R&D sides of the hot cell.

Adjacent to that would be the central receiving station for all other radioactive and short-exposure samples not in the reactor core components. This area, while not a hot cell, would provide personnel protection (*i.e.*, shielding and controlled ventilation) for preliminary sample preparation and examination. It also would provide interim irradiated sample storage prior to delivery to the designated processing laboratory. When needed, samples would be transported remotely to the processing laboratories by the conveyor system.

Irradiated R&D samples introduced into the hot cell could be processed or examined using manipulators within the hot cell. Samples could also enter the R&D suite of lab rooms through the hot cell port into a hot cell or glovebox. From there, they could be moved to additional R&D laboratory rooms within a controlled environment.[14]

6.5.2 Nonproliferation Assessment

6.5.2.1 Relevant Nuclear Materials

Medical and industrial isotope production targets and products, as defined in the Draft NI PEIS, are not considered SNM and are not subject to DOE safeguards except as required for property protection. Many of the isotopes under consideration for production are extremely radioactive (*e.g.*, Co-60) and are subject to stringent controls and regulations to protect the health and safety of workers and the general public but these regulations are not associated with proliferation prevention.

Civil nuclear energy R&D materials that are stored or processed at a new support facility would be subject to the same controls and regulations discussed above for other isotope targets. As such, the above discussion is inclusive of these materials.

[14] Draft NI PEIS, Chapter 2

6.5.2.2 TECHNICAL AND POLICY FACTORS ANALYSIS

6.5.2.2.1 Technical Factors

Assuring Against Theft or Diversion. There is currently no DOE plan or intention to use a new support facility to process or store SNM or ANM as part of the mission described in the Draft NI PEIS. As such, there are no nuclear materials of diversion concern. ● *Fully meets nonproliferation objectives.*

Facilitating Cost-Effective International Monitoring. A new support facility is not being considered under the Draft NI PEIS for a mission involving SNM or ANM. As such, there is no need for international monitoring. ● *Fully meets nonproliferation objectives.*

Results in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. A new support facility is not being considered under the Draft NI PEIS for a mission involving SNM or ANM. ● *Fully meets nonproliferation objectives.*

6.5.2.2.2 Policy Factors

Maintaining Consistency with U.S. Nonproliferation Policy. Because a new support facility would not separate Pu-239, require unnecessary civil use of HEU, or infringe on existing international agreements, use of this facility for the purpose described by the Draft NI PEIS is consistent with U.S. nonproliferation policy. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. The mission described for a new support facility in the Draft NI PEIS does not include any activity that would encourage plutonium reprocessing. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. The mission described for a new support facility in the Draft NI PEIS does not include any activity that would produce fissile material potentially useful for nuclear explosives. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. The mission described for a new support facility in the Draft NI PEIS does not include any activity that should be captured under an FMCT. The new support facility should remain available for international monitoring in the event that hot cell activities are captured under an FMCT because of some similarity to plutonium reprocessing. If a new support facility is selected to produce Pu-238, a U.S. commitment to reserve the facility for civil nuclear programs would mitigate any concerns about future international monitoring access. ● *Fully meets nonproliferation objectives.*

6.6 SUMMARY ASSESSMENTS: SAVANNAH RIVER SITE AND LOS ALAMOS NATIONAL LABORATORY OPERATIONS

SRS neptunium storage and processing operations are not captured by the Draft NI PEIS since they are covered under a previous National Environmental Protection Act (NEPA) action.[15] However, to comprehensively evaluate each of the alternatives and options described in Draft NI PEIS, the nonproliferation impact of the continued storage, oxidation processing, and possible removal of

[15] *Final Environmental Impact Statement, Interim Management of Nuclear Materials at the Savannah River Site,* DOE/EIS-0220, October, 1995.

neptunium from SRS must be addressed. Since these operations are not part of the current NEPA action, the analysis presented is more cursory than those of other facilities considered in this assessment.

SRS has a long history of special nuclear material production for defense use. As part of past reprocessing campaigns at the site, neptunium was recovered and stockpiled. The stockpile of neptunium is currently stored at SRS in the form of neptunium nitrate solution. The current plan under the governing NEPA action is to stabilize this material by converting it into neptunium dioxide powder – the most chemically stable neptunium compound.[16] This involves complex bulk processing of ANM in a former defense production facility.

However, as a legacy of past defense complex operations, there is no realistic alternative to interim storage of the material at SRS. Furthermore, stabilization of the material is required for health, safety, and environmental protection reasons prior to shipment or long term storage at any site regardless of how the material is finally disposed. Since the facility missions described are required regardless of the outcome of a Record of Decision on the Final NI PEIS, there is no additional marginal proliferation risk added (in any factor dimension) by required SRS operations on any of the missions, facilities, alternatives, and options described in the Draft NI PEIS. As such, the SRS operations have no substantive impact on the conclusions reached in this NI NIA.

Similarly, the production of radioisotope power and heating units (using Pu-238) by Los Alamos National Laboratory (LANL) for use by NASA programs is not discussed in depth in this assessment for two reasons: 1) Pu-238 in the isotopic concentrations involved is not a nuclear proliferation concern, and 2) production of these units for NASA is a current and ongoing mission of the Laboratory. Since the LANL operations described are independent of the outcome of a Record of Decision on the Final NI PEIS, there is no additional marginal proliferation risk added (in any factor dimension) by LANL operations on any of the missions, facilities, alternatives, and options described in the Draft NI PEIS. As such, the LANL operations have no substantive impact on the conclusions reached in this NI NIA.

[16] The neptunium dioxide conversion process is described briefly in the Draft NI PEIS in Appendix A.

7 SUMMARY OF FACILITY ASSESSMENTS

7.1 FACILITY ASSESSMENTS

The detailed facility assessments presented in Sections 4 through 6 are summarized below. The facility assessments include all the relevant mission areas that are described in the Draft NI PEIS. Table 7-1 shows the facilities that have been evaluated and graded against the nonproliferation technical and policy factors defined in Section 3. The also shows the current status of the facility and the section that contains the detailed nonproliferation assessment of the facility.

Table 7-1. Facilities Identified in the Draft NI PEIS

Type	Name	Acronym	Location	Status
Irradiation	Fast Flux Test Facility	FFTF	Hanford, WA	Standby
	Advanced Test Reactor	ATR	Idaho National Energy and Environmental Laboratory (INEEL), ID	Operational
	High Flux Isotope Reactor	HFIR	Oak Ridge National Laboratory (ORNL), TN	Operational
	Commercial Light Water Reactor	CLWR	Existing CLWR site to be determined	Operational
	New High-Energy Accelerator New Low-Energy Accelerator	- -	Existing DOE site to be determined	- -
	New Research Reactor	-	Existing DOE site to be determined	-
Target Fabrication and Processing	Radiochemical Engineering Development Center	REDC	Oak Ridge National Laboratory (ORNL), TN	Operational
	Fluorinel Dissolution Process Facility CPP-651	FDPF CPP-651	Idaho National Energy and Environmental Laboratory (INEEL), ID	FDPF: Non-operational Available CPP-651: Operational
	Fuels and Materials Examination Facility	FMEF	Hanford, WA	Non-operational Available
	Radiochemical Processing Laboratory Building 306-E	RPL 306-E	Hanford, WA	Operational
	New Support Facility	-	Existing DOE site to be determined	-

Table 7-2 shows the summary of the detailed facility assessment grades without exercising any nonproliferation concern or uncertainty mitigation approaches. Facilities and mission cases (*e.g.*, FFTF standby/deactivation, neptunium storage) are shown across rows and nonproliferation assessment technical and policy factors are shown down columns. There are a few cases of nonproliferation concerns and uncertainty. Even so, it should be noted that *there are currently no U.S. nonproliferation policies, laws, regulations or international agreements that preclude the use of any of the facilities in the manner described in the Draft NI PEIS.*

7.2 MITIGATION APPROACH TO IMPROVE FACILITY ASSESSMENTS

The nonproliferation concerns and uncertainties are associated with the Pu-238 processing mission at processing facilities. The material forms technical factor (the third technical factor) cannot be mitigated since neptunium must be separated and purified as part of the Pu-238 processing mission (in a target post-irradiation processing facility). This is always the case and is technically unavoidable (even if Pu-238 is purchased from Russia, this process is required in a Russian nuclear facility).

Table 7-2. Assessments of Facilities as Described in the Draft NI PEIS

		Irradiation Facilities								***Target Fabrication and Processing Facilities***						***Np-237 Storage***		
		FFTF Restarted	FFTF Standby/Deactivated	ATR	HFIR	CLWR	New Low-Energy Accelerator	New High-Energy Accelerator	New Research Reactor	REDC	FDPF	FMEF	RPL	306-E	New Support Facility	REDC	CPP-651	FMEF
Technical Factors	Assuring Against Theft or Diversion	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Facilitating Cost-Effective International Monitoring	●	●	●	●	●	●	●	●	●	○	●	●	●	●	●	●	●
	Resulting in Final Material Forms from which Retrieval is More Difficult than from Original Material Forms	●	●	●	●	●	●	●	●	◑	◑	◑	●	●	●	●	●	●
Policy Factors	Maintaining Consistency with U.S. Nonproliferation Policy	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Avoiding Encouragement of Plutonium Reprocessing	●	●	●	●	●	●	●	●	●	◑	●	●	●	●	●	●	●
	Building Confidence that the U.S. is not Producing Material for Nuclear Weapons	●	●	●	●	●	●	●	●	●	◑	●	●	●	●	●	●	●
	Supporting Negotiation of a Verifiable FMCT	●	●	●	●	●	●	●	●	●	○	●	●	●	●	●	●	●

● *Fully meets nonproliferation objectives*
◑ *Might raise nonproliferation concerns*
○ *Raises nonproliferation concerns*

Most of the concerns and uncertainties surrounding the use of FDPF are associated with its history as a defense programs facility and the resulting lack of transparency that could be available in the event that international monitoring becomes desirable under an FMCT. Mitigation of nonproliferation concerns and uncertainties for the FDPF would require a vulnerability assessment to determine the national security risk of a managed access regime that would be required for verification of an FMCT. Furthermore, while all nuclear fuel cycle related activities are captured under the Additional Protocol, FDPF (and many other defense and national security program facilities) would exercise national security exclusion rights under Article 1, effectively eliminating that transparency mechanism. While it may be possible to grant managed access to verify an FMCT, Additional Protocol access would not be permitted because of environmental sampling access rights granted to the IAEA under Articles 5, 6 and 9 of the Protocol. However, invasive Additional Protocol access should not be required to provide sufficient transparency to mitigate concerns and uncertainties associated with FDPF.

The Additional Protocol was designed to capture clandestine nuclear weapons program facilities in non-nuclear-weapon states. Since it is well known that FDPF has a long history of Navy defense missions, and since the described mission does not involve the production of special fissionable material (SFM), sufficient transparency might be provided by a managed access regime that would meet the requirements of FMCT verification. *If managed access can be granted to the FDPF, sufficient for verification of an FMCT, the uncertainties and concerns associated with the use of FDPF for the Pu-238 processing mission would be effectively mitigated (with the exception of the material forms technical factor).*

8 ASSESSMENTS OF ALTERNATIVES AND OPTIONS

8.1 REVIEW OF ALTERNATIVES AND OPTIONS

The alternatives and options described in the Draft NI PEIS were introduced and discussed in Section 1. The table summarizing the alternatives and options is reproduced below as Table 8-1.

Table 8-1. Alternatives and Options Defined in the Draft NI PEIS

Alternatives	**Options**	**Irradiation Facility**	**Pu-238 Production Mission**		**Medical and Industrial Isotope Production and Nuclear Energy Research and Development Mission**	
			Storage Facility	*Processing Facility*	*Storage Facility*	*Processing Facility*
No Action Alternative[d, e]	1	-	-	-	-	-
	2	-	REDC	-	-	-
	3	-	CPP-651	-	-	-
	4	-	FMEF	-	-	-
Alternative 1: *Restart FFTF*[g]	1	FFTF[a]	REDC	REDC	RPL/306-E	RPL/306-E
	2	FFTF[a]	FDPF/CPP-651	FDPF	RPL/306-E	RPL/306-E
	3	FFTF[a]	FMEF	FMEF	FMEF	FMEF
	4	FFTF[b]	REDC	REDC	RPL/306-E	RPL/306-E
	5	FFTF[b]	FDPF/CPP-651	FDPF	RPL/306-E	RPL/306-E
	6	FFTF[b]	FMEF	FMEF	FMEF	FMEF
Alternative 2: *Use Only Existing Operational Facilities*[f]	1	ATR	REDC	REDC	-	-
	2	ATR	FDPF/CPP-651	FDPF	-	-
	3	ATR	FMEF	FMEF	-	-
	4	CLWR	REDC	REDC	-	-
	5	CLWR	FDPF/CPP-651	FDPF	-	-
	6	CLWR	FMEF	FMEF	-	-
	7	HFIR/ATR	REDC	REDC	-	-
	8	HFIR/ATR	FDPF/CPP-651	FDPF	-	-
	9	HFIR/ATR	FMEF	FMEF	-	-
Alternative 3: *Construct New Accelerators*[f, g, h]	1	New	REDC	REDC	New[c]	New[c]
	2	New	FDPF/CPP-651	FDPF	New[c]	New[c]
	3	New	FMEF	FMEF	New[c]	New[c]
Alternative 4: *Construct New Research Reactor*[f]	1	New	REDC	REDC	New[c]	New[c]
	2	New	FDPF/CPP-651	FDPF	New[c]	New[c]
	3	New	FMEF	FMEF	New[c]	New[c]
Alternative 5: *Permanently Deactivate FFTF (with no new missions)*[d]	-	-	-	-	-	-

a) FFTF operates with MOX fuel for 21 years and uranium fuel for 14 years.
b) FFTF operates with MOX fuel for 6 years and uranium fuel for 29 years.
c) The New Support Facility would not be required if a DOE site with available support capability and infrastructure is selected.
d) Under the No Action Alternative (all options) and Alternative 5, Pu-238 is purchased from Russia to supply NASA programs.
e) Under the No Action Alternative, FFTF is maintained in standby mode indefinitely.
f) Under Alternatives 2, 3, and 4, the FFTF is permanently deactivated.
g) The ATW placeholder is not evaluated in this NI NIA. The ATW program will be the topic of a future ATW NIA.
h) A new low-energy accelerator might also be combined with reactor options under Alternative 2 to fulfill all proposed missions.

8.2 GENERIC ASSESSMENT OF THE RUSSIAN PLUTONIUM-238 PURCHASE OPTION

Under the No Action Alternative (all options) and Alternative 5, the Department would continue to exercise an option to purchase Pu-238 from Russia. As such, it is necessary to assess the nonproliferation merits and drawbacks of exercising the Russian purchase option. There are essentially three approaches to evaluate the purchase option:

- Perform a comprehensive nonproliferation assessment of the Russian nuclear infrastructure associated with the continued production of Pu-238.
- State that since Russia has an ongoing spent nuclear fuel reprocessing and isotope recovery program (that includes the recovery of neptunium and the production of Pu-238), that exercising the Russian Pu-238 purchase option does not increase the marginal proliferation risk.
- Evaluate the Russian Pu-238 production mission in a generic fashion without detailed information about specific facilities.

Publication of a comprehensive U.S. nonproliferation assessment of the Russian Pu-238 program might be politically sensitive (or classified), triggering official U.S. concerns about public dissemination of the document. Furthermore, a detailed evaluation of a foreign nuclear program is beyond the scope of this NI NIA of proposed domestic civil nuclear programs.

Assessing the Russian Pu-238 program as having no marginal impact on proliferation risk since it is an ongoing program seems upon first consideration to be a logical approach. However, this approach would unduly and artificially penalize future U.S. civil nuclear programs since decisions to either restart U.S. programs or begin new programs would automatically be at a disadvantage when compared to ongoing foreign programs. The unintended consequence of such an approach over time could be deleterious to U.S. civil nuclear programs in general. Furthermore, such an approach might leave the false impression that DOE nonproliferation experts believe that Russian or other foreign programs have superior domestic safeguards and nonproliferation credentials than comparable U.S. programs.

In order to avoid the pitfalls discussed above, the Department has elected to evaluate the proliferation risk of the Russian purchase option in a generic fashion by considering the Russian Pu-238 production mission without making detailed assumptions about involved nuclear facilities. This approach should not be interpreted as indicating that the Department believes that this represents a comprehensive assessment of the Russian purchase option but rather that the Department believes that it is both reasonable and fair to evaluate the Russian purchase option to flag generic nonproliferation uncertainties and concerns.

Since this is an assessment of an entirely generic system, it does not make sense to break it down into separate undefined facilities. Rather, the Russian purchase option assessment is derived from a total “system” level perspective.

8.2.1 Relevant Nuclear Materials

The Russian Pu-238 purchase option described in the Draft NI PEIS requires the production and irradiation of neptunium targets. Neptunium targets are typically made of purified, concentrated neptunium dioxide. The production of Pu-238 requires the production of purified neptunium dioxide from neptunium solution followed by target fabrication, irradiation to build in Pu-238 via neutron capture and beta decay, solvent extraction and ion exchange processing to separate and purify neptunium and Pu-238 from fission products and other waste products, and a repeat of the cycle to produce further Pu-238. Each cycle destroys neptunium since neptunium is converted to Pu-238 in the process. During the production cycle, neptunium is in different solid (*e.g.,* oxide powders and pressed solid matricies) and liquid forms (*e.g.,* nitrate solutions). Neptunium is an alternate nuclear material (ANM).[1] The utility of ANM in nuclear weapons is recognized by the U.S. Government and the international community.

During the Pu-238 production cycle, Pu-238 is in different solid (*e.g.,* oxide powders and pressed solid matricies) and liquid forms (*e.g.,* nitrate solutions). During the process of building Pu-238 into neptunium targets, a small amount of Pu-239 is also produced by second neutron captures by Pu-238. Since the desired product is relatively pure Pu-238, the secondary production of Pu-239 is intentionally limited. This limits the build in of Pu-238 to about 10% to 15% of the neptunium content of the fresh target. Plutonium that is more than 80% Pu-238 is not considered a nuclear proliferation threat by the international safeguards community.

8.2.2 Technical and Policy Factors Analysis

8.2.2.1 TECHNICAL FACTORS

Assuring Against Theft or Diversion. The current status of Russian domestic safeguards of ANM is unknown. As a result, there is *significant uncertainty* in this regard. As a nuclear-weapon state, Russia is obligated under the international ANM monitoring agreement to report exports and export denials of ANM. ◑ *Might raise nonproliferation concerns.*

Facilitating Cost-Effective International Monitoring. As a nuclear-weapon state, Russia is obligated under the international ANM monitoring agreement to report exports and export denials of ANM. Since recovery of Pu-238 from neptunium targets involves chemical processes comparable to traditional Pu-239 reprocessing, it is possible that Russian facilities would be captured under a future FMCT international monitoring regime. Since it is not known whether a Russian facility would be made available for international monitoring, as a result of past and ongoing national security programs at the facility, there is *significant uncertainty* as to whether international monitoring would be permitted in a Russian Pu-238 processing facility. ◑ *Might raise nonproliferation concerns.*

Resulting in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. The recovery of Pu-238 from neptunium targets involves chemical processes that separate and purify neptunium and Pu-238 from irradiated target material. As such, ANM is recovered and purified (put into a more retrievable form) for further irradiation. However, each time targets are processed, the amount of neptunium is reduced by the amount of the production rate of Pu-238 plus waste product isotopes such that significant amounts of neptunium are consumed over repeated Pu-238 production cycles. However, Russia still reprocesses spent nuclear fuel and may be recovering additional stocks of fresh neptunium. Furthermore, irradiated neptunium is processed and neptunium is put into a final material form that is easier to retrieve for use in a nuclear explosive. The continued production of fresh neptunium and neptunium recycle in the Russian nuclear program raises a *significant identified concern.* ○ *Raises nonproliferation concerns.*

8.2.2.2 POLICY FACTORS

Maintaining Consistency with U.S. Nonproliferation Policy. It is consistent with U.S. nonproliferation policy to support peaceful, civil Russian programs as part of the overall U.S. nuclear threat reduction strategy. The Russian purchase option is representative of that general philosophy since Russian

[1] See Section 2.1.8

production of Pu-238 for NASA program consumption is a civil mission that engages Russian nuclear technologists in peaceful, constructive efforts. Because the Russian purchase option would not require separation of Pu-239, require unnecessary civil use of highly enriched uranium (HEU), or infringe on existing international agreements, use of this option for the purpose described by the Draft NI PEIS is consistent with U.S. nonproliferation policy. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. Production of Pu-238 from neptunium targets involves chemical processes that are comparable to traditional Pu-239 reprocessing (albeit on a very small scale). However, Pu-238 production does not separate Pu-239 and therefore does not constitute "plutonium reprocessing" as the term is understood in existing U.S. nonproliferation policy. Furthermore, it can be reasonably argued that the quantities of Pu-238 purchased under the Russian purchase option do not require the continued reprocessing of spent nuclear fuel for the purpose of increasing Russian neptunium stocks (just as it would not in a domestic Pu-238 production program). As such, continued U.S. purchases of Russian Pu-238 do not encourage plutonium reprocessing. ● *Fully meets nonproliferation objectives.*

Building Confidence that Russia is Not Producing Material for Nuclear Weapons. Russian production of Pu-238 is a miniscule operation when compared against the backdrop of continued commercial spent nuclear fuel reprocessing in dual-use (military/civil) Russian facilities. When taken in this context, continued Russian Pu-238 production does not represent a significant added risk nor does it significantly reduce (or improve) confidence that Russia has ceased producing material for nuclear weapons. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. Since the processes used by the Russian Pu-238 production mission might be captured under a FMCT because of their similarity to Pu-239 reprocessing, it is essential that programs be implemented in the Russian facility in such a manner as to allow international monitoring under a FMCT. If the Russian facility is made available for international monitoring, then any concern that it might impact FMCT verification would be effectively mitigated. However, since the availability of the Russian facility for international monitoring is *significantly uncertain*, monitoring may not be possible and Russian assurances may not provide sufficient transparency to satisfy the requirements for a future FMCT. ◑ *Might raise nonproliferation concerns.*

8.2.3 Mitigation Approach to Improve the Russian Purchase Option Assessment

To help mitigate the uncertainty surrounding Russian ANM domestic safeguards practices, the United States could elect to engage the Russian side through existing programs to both explore and look for opportunities to improve on Russian ANM domestic safeguards practices. *If the United States had sufficient confidence concerning the rigor of Russian controls on ANM, this uncertainty would be effectively mitigated.*

The nonproliferation concerns and uncertainties are associated with the Russian Pu-238 processing mission at Russian processing facilities. The material forms technical factor (the third technical factor) cannot be fully mitigated since neptunium must be separated and purified as part of the Pu-238 processing mission (in a target post-irradiation processing facility). This is always the case and is technically unavoidable. *However, if Russia were to implement a moratorium on spent nuclear fuel reprocessing, this factor would be partially mitigated to "◑ might raise nonproliferation concerns" – similar to the U.S. program assessments.*

Other concerns and uncertainties surrounding the use of a Russian facility are associated with its history as a defense programs facility and the resulting potential lack of transparency that could be available in the event that international monitoring becomes desirable under an FMCT. Mitigation of nonproliferation concerns and uncertainties for a Russian facility would require a vulnerability assessment (performed by Russia) to determine the national security risk of a managed access regime that would be required for verification of an FMCT. *If managed access can be granted to the Russian facility, sufficient for verification of an FMCT, the uncertainties and concerns associated with the use of a Russian facility for the Pu-238 processing mission would be effectively mitigated (with the exception of the material forms technical factor).*

8.3 GENERIC ASSESSMENT OF REQUIRED NUCLEAR MATERIAL TRANSPORTATION

The various alternatives defined in the Draft NI PEIS are constructed around irradiation facilities. Options arise under each alternative as a result of electing different target fabrication and processing facilities to support the proposed missions. As a result, assessments of alternatives and options require an evaluation of proliferation risks associated with transportation of nuclear materials.

In order to implement any of the alternatives or options defined in the Draft NI PEIS, including the No Action Alternative and Alternative 5 (permanently deactivate FFTF with no new missions), transportation of attractive nuclear materials will be required. The nuclear materials that will require transportation vary with the alternatives and options as do the transportation frequency and mileage that may be required under each option. For example, in the case of Alternative 5, Category I, Attractiveness C materials in the form of fresh Hanford mixed oxide (MOX) fuel would have to be disposed of in addition to spent MOX fuel from past Fast Flux Test Facility (FFTF) operations in order to finish deactivation of the Hanford 400 Area (the FFTF site). Furthermore, neptunium oxide will require disposition that will involve transportation of equally attractive nuclear material even if that transportation occurs only within the Savannah River Site (SRS).

Since all alternatives and options described by the Draft NI PEIS involve the transportation of attractive nuclear materials, it is not necessary to evaluate each case but rather, a brief assessment of the proliferation risks associated with nuclear material transportation in a generic sense will suffice for all cases. Since the greatest proliferation concerns are associated with the transportation of attractive nuclear materials, prior to making that assessment it is worthwhile to briefly summarize the level of physical protection that is applied in the transportation of attractive nuclear materials described in Section 2. For greater detail, please see the summary given in the Draft NI PEIS – Appendix J.

8.3.1 DOE Safeguarded Domestic Transportation

DOE anticipates that any transportation of fresh neptunium oxide, Pu-238 oxide, MOX fuel, or highly enriched uranium (HEU) could require the use of the Transportation Safeguards System (TSS) and shipment using Safe-Secure Trailers/Safeguarded Transport (SST/SGT) if the materials shipped rise to the attractiveness regulations that stipulate such methods. Use of the TSS is required for 1) nuclear explosives, 2) components that could comprise a complete nuclear explosive in a single shipment, 3) 5 kilograms (kg) or more U-235 in any form of uranium enriched above 20%, or 2 kg or more of any form of U-233 or plutonium, 4) classified forms of plutonium or uranium regardless of quantity, 5) DOE-owned plutonium in any quantity to be transported by air, and 6) any form of isotopically concentrated Pu-238 (plutonium that is greater than 10% Pu-238) in excess of 5 grams.

Since neptunium is treated as pure U-235 with respect to domestic safeguards, 5 kg or more in any form (enrichment does not apply to neptunium) qualifies for shipment via the TSS. Although material that contains plutonium that is greater than 60% Pu-238 is treated as Attractiveness Level E (All Other Materials) this material is rigorously protected against loss, theft and sabotage (through physical protection and accounting) and is strictly contained (to prevent accidental release) as a result of the health and safety risks presented by the material. Under DOE safeguards, Pu-238 is reportable in 0.1 gram quantities. Since the amount of neptunium that will be required per year in a typical 5 kg Pu-238 production operation will generally on the order of 50 kg (heavy metal mass) in oxide (or more), it is likely that overland shipments of neptunium oxide will require transport via SST/SGT unless it is broken into several smaller shipments.[2] Furthermore, with a 5 gram threshold on Pu-238, SST/SGT transport will be required for all Pu-238 shipments.

Since its establishment in 1975, the DOE Transportation Safeguards Division has accumulated over 94 million miles of over-land transportation of attractive DOE-owned nuclear materials without fatality, release of radioactive material, or theft or loss of nuclear materials. Although details of operational plans and vehicle safeguards enhancements are classified, some safeguards characteristics of the SST/SGT system include:

- Established and tested operational and emergency plans and procedures for shipment of nuclear materials.
- Various deterrents to prevent theft of nuclear materials.
- Armored tractor that provides courier protection against attack and contains advanced communications equipment.
- Specially designed escort vehicles containing advanced communications equipment and additional couriers.
- Twenty-four hour real-time communications to monitor location and status of all SST/SGT shipments via DOE's Security Communication System.
- Couriers, who are armed Federal officers, receive rigorous specialized training and are closely monitored through DOE's Personnel Security Assurance Program.
- Stringent maintenance standards on all equipment.
- Conduct of periodic appraisals of TSS operations by the DOE Office of Defense Programs to ensure compliance with DOE Orders and management directives.
- Continuous improvement is transportation and emergency management programs.

8.3.2 International Safeguarded Overseas Shipment of German MOX Fuel

If German MOX fuel is imported to the United States for disposition in the FFTF, the fuel would be shipped via "purpose-built" vessel to a U.S. military port. A purpose-built vessel is a ship specially designed to transport nuclear materials. In addition to features that rigorously protect the environment, these vessels meet all international conventions and U.S. regulations governing the safeguards and security of attractive nuclear materials.[3] Although the United States does not own purpose-built vessels (they are owned by Britain, Japan and Sweden), the United States has used purpose-built vessels to ship U.S. origin HEU reactor fuel from foreign research reactors to the United States as part of the Department's Foreign Research Reactor Spent Nuclear Fuel Acceptance Program.

[2] In the case of several smaller shipments, shipments will be in compliance with all U.S. regulations regarding transportation of attractive nuclear materials.
[3] See Appendix 10.1.7.4

8.3.3 Technical and Policy Factors Analysis

8.3.3.1 TECHNICAL FACTORS

Assuring Against Theft or Diversion. Required nuclear material transport is subject to both domestic regulations (DOE Orders) and International Conventions and international safeguards Agreements (depending upon material ownership and agreements that may encumber the material).[4] In the case of DOE-owned materials not under international safeguards, DOE Orders would be in force during material transportation. As discussed above, these systems are both highly developed and successful, reducing the risk of theft to a very low level during transportation and material delivery. In the event that material under DOE custody is also subject to international safeguards, there are mechanisms that could be exercised that would allow the DOE to provide sufficient transparency to guarantee "continuity of knowledge" to the International Atomic Energy Agency (IAEA) during transportation and material delivery. ● *Fully meets nonproliferation objectives.*

Facilitating Cost-Effective International Monitoring. Nuclear materials that are under international safeguards during overseas shipping operations (as the German MOX fuel would be) are subject to international monitoring. In the event that material under DOE custody is also subject to international safeguards, there are mechanisms that could be exercised that would allow the DOE to provide sufficient transparency to guarantee "continuity of knowledge" to the International Atomic Energy Agency (IAEA) during transportation and material delivery, facilitating cost-effective international monitoring. ● *Fully meets nonproliferation objectives.*

Resulting in Final Material Forms from which Retrieval is More Difficult Than from Original Material Forms. Transportation operations do not modify the attractiveness of nuclear materials. ● *Fully meets nonproliferation objectives*

8.3.3.2 POLICY FACTORS

Maintaining Consistency with U.S. Nonproliferation Policy. Transportation operations would not separate Pu-239, require unnecessary civil use of HEU, or infringe on existing international agreements. ● *Fully meets nonproliferation objectives.*

Avoiding Encouragement of Plutonium Reprocessing. Transportation operations do not include any activities that would encourage plutonium reprocessing. ● *Fully meets nonproliferation objectives.*

Building Confidence that the United States is Not Producing Material for Nuclear Weapons. Transportation operations do not include any activities that produce fissile material potentially useful for nuclear explosives. ● *Fully meets nonproliferation objectives.*

Supporting Negotiation of a Verifiable FMCT. Transportation operations do not include any activities that could be captured under an FMCT. ● *Fully meets nonproliferation objectives.*

8.3.4 General Comments about the Generic Transportation Assessment

[4] Ibid.

In view of the outstanding records of the Department's Transportation Safeguards Division and the British, Japanese and Norwegian corporations that operate purpose-built vessels, it is the Department's position that transportation adds only a negligible increase to the proliferation risk of the various alternatives and options. In other words, minimization of transportation is not considered to greatly reduce proliferation risk when compared to other factors.

Therefore, if all other things are essentially equal between options under consideration, then the limited effect of transportation should be considered. When considering the effect of transportation, the frequency of shipper-receiver "hand-offs" is likely more important than the mileage traveled since each change in custody involves material accounting operations.

8.4 ASSESSMENTS OF ALTERNATIVES AND OPTIONS

To roll-up assessments for the 26 different alternatives and options presented in Table 8-1, all facility, mission and transportation elements were figured into a weak link analysis. This analysis is presented in Table 8-2. The table shows the nonproliferation assessment technical and policy factors across the rows and the rolled-up alternatives and options down the columns. To construct a particular alternative/option assessment, each element of the given alternative and option (facilities [mission], Russian Pu-238 purchase option, transportation) is considered and the weakest grade under a given technical or policy factor is selected to represent the assessment grade under that factor for the alternative and option under consideration.[5]

Since all the nonproliferation uncertainties and concerns involve the use of post-irradiation processing facilities,[6] the alternative and option assessments are entirely determined by which facility is used to process irradiated neptunium targets under the Pu-238 production mission. Table 8-2 shows the alternatives and options weak link assessments. Under the No Action Alternative (all options) and Alternative 5, the overall assessment is determined by the Russian purchase option assessment (Section 8.1). The mitigation approach for alternative and option assessments are identical to those discussed in Sections 7.2 and 8.1.

[5] For more detailed discussion of the analysis approach refer to Section 3.
[6] Except for the Russian purchase option assessment which is a "system" level generic assessment.

Table 8-2. Assessments of Alternatives and Options as Defined in the Draft NI PEIS

		Technical Factors			*Policy Factors*			
Alternatives	***Options***	Assuring Against Theft or Diversion	Facilitating Cost-Effective International Monitoring	Resulting in Final Material Forms from which Retrieval is More Difficult than from Original Material Forms	Maintaining Consistency with U.S. Nonproliferation Policy	Avoiding Encouragement of Plutonium Reprocessing	Building Confidence that the U.S. (Russia)* is not Producing Material for Nuclear Weapons	Supporting Negotiation of a Verifiable FMCT
No Action Alternative*	1	◑	◑	○	●	●	●	◑
	2	◑	◑	○	●	●	●	◑
	3	◑	◑	○	●	●	●	◑
	4	◑	◑	○	●	●	●	◑
Alternative 1: *Restart FFTF*	1	●	●	◑	●	●	●	●
	2	●	○	◑	●	◑	◑	○
	3	●	●	◑	●	●	●	●
	4	●	●	◑	●	●	●	●
	5	●	○	◑	●	◑	◑	○
	6	●	●	◑	●	●	●	●
Alternative 2: *Use Only Existing Operational Facilities*	1	●	●	◑	●	●	●	●
	2	●	○	◑	●	◑	◑	○
	3	●	●	◑	●	●	●	●
	4	●	●	◑	●	●	●	●
	5	●	○	◑	●	◑	◑	○
	6	●	●	◑	●	●	●	●
	7	●	●	◑	●	●	●	●
	8	●	○	◑	●	◑	◑	○
	9	●	●	◑	●	●	●	●
Alternative 3: *Construct New Accelerator(s)*	1	●	●	◑	●	●	●	●
	2	●	○	◑	●	◑	◑	○
	3	●	●	◑	●	●	●	●
Alternative 4: *Construct New Research Reactor*	1	●	●	◑	●	●	●	●
	2	●	○	◑	●	◑	◑	○
	3	●	●	◑	●	●	●	●
Alternative 5: *Permanently Deactivate FFTF (with no new missions)**	-	◑	◑	○	●	●	●	◑

* Under the No Action Alternative (Options 1-4) and Alternative 5, the Russian Pu-238 purchase option is considered.

● *Fully meets nonproliferation objectives*

◑ *Might raise nonproliferation concerns*

○ *Raises nonproliferation concerns*

9 CONCLUSIONS AND RECOMMENDATIONS

There are currently no U.S. nonproliferation policies, laws, regulations or international agreements that preclude the use of any of the facilities in the manner described in the Draft NI PEIS. However, there are a limited number of nonproliferation concerns and uncertainties that might be mitigated to increase the number of alternatives and options that have optimum nonproliferation qualities for the missions described in the Draft NI PEIS. Definitions of the alternatives and options, proposed in the Draft NI PEIS, are given in Table 8-1 and are described along with proposed missions in Section 1. Facilities are described in Sections 4 through 6. An overall assessment is made of the proposed missions, independent of the facilities, alternatives, and options identified in the Draft NI PEIS. Identification of the nonproliferation most and least favorable alternatives and options are presented below followed by some special considerations for Fast Flux Test Facility (FFTF) restart and recommended mitigation approaches to improve less favorable alternatives and options.

9.1 OVERALL ASSESSMENT OF MISSIONS PROPOSED IN THE DRAFT NI PEIS

The missions (independent of selected facilities) proposed in the Draft NI PEIS are evaluated by using a "most favorable realizable path" analysis. The analogy being that if attainment of a goal is desirable but may be pursued along several different paths, the most favorable realizable path is most representative of the minimum "cost" in a cost/benefit analysis of attaining the goal. The minimum nonproliferation impact is the "cost" consideration in a nonproliferation impact assessment. As a result, a proposed mission is assessed to be equivalent to the most favorable nonproliferation option that accomplishes a particular mission.

Medical, Industrial, and Research Isotope Production. There *are no significant identified concerns* that have been identified demonstrating how, within the bounds of the description given in the Draft NI PEIS, the pursuit of the medical, industrial, and research isotope production mission is contrary to U.S. nonproliferation objectives as defined by any assessment factor. Therefore, this mission is graded as ● *fully meets nonproliferation objectives.*

Plutonium-238 Production. With the exception of the third technical assessment factor, *reduction in attractiveness of material forms* (see Section 3), there *are no significant identified concerns* that have been identified demonstrating how, within the bounds of the description given in the Draft NI PEIS, the pursuit of the Pu-238 production mission is contrary to U.S. nonproliferation objectives as defined by the remaining technical and policy assessment factors. Therefore, these remaining factors are graded as ● *fully meets nonproliferation objectives.* In the case of the third technical assessment factor, the process of producing, recovering, and purifying Pu-238 requires that neptunium (an alternate nuclear material) also be recovered, purified, and recycled. However, in the event that Pu-238 production is resumed in the United States, the total separated stock of neptunium will be reduced over time in an irreversible manner since there is a moratorium on U.S. spent fuel reprocessing. This overall reduction in a weapons-usable material stock is a partial mitigation of the identified concern. As a result, *there is significant uncertainty* raised with respect to the third technical assessment factor, and that single factor is graded as ◑ *might raise nonproliferation concerns.* However, it should be pointed out that this issue is unavoidable (unless the United States elects to neither produce nor purchase Pu-238) and impacts all alternatives and options including the No Action Alternative and Alternative 5: permanently deactivate FFTF with no new missions at U.S. facilities.

Civil Nuclear Energy Research and Development. The DOE Office of Nuclear Energy has included Accelerator Transmutation of Waste (ATW) as one of many possible future civil nuclear energy research and development (R&D) missions as a placeholder in the event that the U.S. Government decides to pursue this technology. Currently, the Department is performing technical paper studies and planning studies (*e.g.*, the “ATW Road Map”) to assist Congress with fiscal and program planning. These efforts are also being reviewed by the independent Nuclear Energy Advisory Committee (NERAC) Subcommittee on the Accelerator Transmutation of Waste, which in its report of May 23, 2000, recommended that, a study should be launched to identify potential proliferation concerns associated with ATW and possible approaches to mitigate identified concerns. A comprehensive nonproliferation impact assessment of the ATW program plan would be performed by the Office of Arms Control and Nonproliferation prior to proceeding beyond paper studies with actual fuels materials testing in support of ATW (or other technologies that include or imply closed fuel cycle technologies). As such, the nonproliferation impact of a possible future ATW program is not considered in this NI NIA since it is not a well-defined, principal identified mission at this time, but it will be considered in a future nonproliferation impact assessment if the ATW Program moves forward. With respect to other identified civil nuclear energy R&D missions, there *are no significant identified concerns* that have been identified demonstrating how, within the bounds of the description given in the Draft NI PEIS, the pursuit of these missions is contrary to U.S. nonproliferation objectives as defined by any assessment factor. In fact, the development of proliferation resistant nuclear fuels and technologies are a significant feature of the intended R&D program. Therefore, this mission is graded as ● *fully meets nonproliferation objectives.*

9.2 NONPROLIFERATION MOST AND LEAST FAVORABLE ALTERNATIVES AND OPTIONS

The nonproliferation most favorable alternatives and options are given in Table 9-1. These alternatives and options are selected by simply extracting those shown in Table 8-2 with the most favorable nonproliferation assessments. The nonproliferation least favorable alternatives and options are given in Table 9-2. These alternatives and options are selected by extracting those shown in Table 8-2 with the least favorable nonproliferation assessments. In short, the options that use the Radiochemical Engineering Development Center (REDC) and the Fuels and Materials Examination Facility (FMEF) have the most favorable assessments and the options that use the Fluorinel Dissolution Process Facility (FDPF) have the least favorable assessments. Options that require Russian Pu-238 purchase score between most and least favorable.

9.3 SPECIAL CONSIDERATIONS FOR ALTERNATIVE 1: RESTART FFTF

If the Nuclear Infrastructure Record of Decision elects to restart FFTF (under any option), there are some special considerations. To codify the assumptions underlying the conclusion that restart of the FFTF fully meets U.S. nonproliferation policy objectives, the Nuclear Infrastructure Record of Decision should include the following commitments:

- The FFTF will not be configured to operate as a breeder reactor (breeding ratio equal to or greater than one) or to optimize the production of plutonium.
- Spent MOX fuel irradiated in the FFTF will not be reprocessed.
- During the period that the FFTF is fueled with Hanford MOX fuel, an analysis will be undertaken by the RERTR program to determine whether the reactor can be fueled with LEU fuel, and if this is shown to be technically feasible, the reactor will be fueled with LEU fuel following the consumption of existing MOX fuel (Hanford and, possibly, German MOX fuel).
- A nonproliferation impact assessment will be prepared on the ATW program prior to the test irradiation of ATW fuels materials in the FFTF.

- The FFTF will remain available for international monitoring.

Table 9-1. Nonproliferation Most Favorable Alternatives and Options as Defined in the Draft NI PEIS

		Technical Factors			*Policy Factors*			
Alternatives	***Options***	Assuring Against Theft or Diversion	Facilitating Cost-Effective International Monitoring	Resulting in Final Material Forms from which Retrieval is More Difficult than from Original Material Forms	Maintaining Consistency with U.S. Nonproliferation Policy	Avoiding Encouragement of Plutonium Reprocessing	Building Confidence that the U.S. is not Producing Material for Nuclear Weapons	Supporting Negotiation of a Verifiable FMCT
Alternative 1: *Restart FFTF*	1	●	●	◑	●	●	●	●
	3	●	●	◑	●	●	●	●
	4	●	●	◑	●	●	●	●
	6	●	●	◑	●	●	●	●
Alternative 2: *Use Only Existing Operational Facilities*	1	●	●	◑	●	●	●	●
	3	●	●	◑	●	●	●	●
	4	●	●	◑	●	●	●	●
	6	●	●	◑	●	●	●	●
	7	●	●	◑	●	●	●	●
	9	●	●	◑	●	●	●	●
Alternative 3: *Construct New Accelerator(s)*	1	●	●	◑	●	●	●	●
	3	●	●	◑	●	●	●	●
Alternative 4: *Construct New Research Reactor*	1	●	●	◑	●	●	●	●
	3	●	●	◑	●	●	●	●

● *Fully meets nonproliferation objectives*
◑ *Might raise nonproliferation concerns*
○ *Raises nonproliferation concerns*

9.4 NONPROLIFERATION UNCERTAINTIES, CONCERNS, AND MITIGATION APPROACH

9.4.1 U.S. Alternatives and Options Mitigation Approach

The nonproliferation concerns and uncertainties are associated with the Pu-238 processing mission at processing facilities. The material forms technical factor (the third technical factor) cannot be mitigated since neptunium must be separated and purified as part of the Pu-238 processing mission (in a target post-irradiation processing facility). This is always the case and is technically unavoidable (even if Pu-238 is purchased from Russia, this process is required in a Russian nuclear facility).[1]

Table 9-2. Nonproliferation Least Favorable Alternatives and Options as Defined in the Draft NI PEIS

		Technical Factors			*Policy Factors*			
Alternatives	***Options***	Assuring Against Theft or Diversion	Facilitating Cost-Effective International Monitoring	Resulting in Final Material Forms from which Retrieval is More Difficult than from Original Material Forms	Maintaining Consistency with U.S. Nonproliferation Policy	Avoiding Encouragement of Plutonium Reprocessing	Building Confidence that the U.S. is not Producing Material for Nuclear Weapons	Supporting Negotiation of a Verifiable FMCT
Alternative 1: *Restart FFTF*	2	●	○	◑	●	◑	◑	○
	5	●	○	◑	●	◑	◑	○
Alternative 2: *Use Only Existing Operational Facilities*	2	●	○	◑	●	◑	◑	○
	5	●	○	◑	●	◑	◑	○
	8	●	○	◑	●	◑	◑	○
Alternative 3: *Construct New Accelerator(s)*	2	●	○	◑	●	◑	◑	○
Alternative 4: *Construct New Research Reactor*	2	●	○	◑	●	◑	◑	○

● *Fully meets nonproliferation objectives*
◑ *Might raise nonproliferation concerns*
○ *Raises nonproliferation concerns*

Most of the concerns and uncertainties surrounding the use of FDPF are associated with its history as a defense programs facility and the resulting lack of transparency that could be available in the event that international monitoring becomes desirable under an Fissile Material Cutoff Treaty (FMCT). Mitigation of nonproliferation concerns and uncertainties for the FDPF would require a vulnerability assessment to determine the national security risk of a managed access regime that would be required for verification of an FMCT. Furthermore, while all nuclear fuel cycle related activities are captured under the Additional Protocol, the United States would likely exercise its right to exempt defense facilities, such as FDPF, for reasons of national security under Article 1 of the Additional Protocol, effectively eliminating that transparency mechanism. While it may be possible to grant managed access to verify an FMCT,

[1] The neptunium/Pu-238 cycle in the proposed U.S. production process does have an important long-term nonproliferation benefit – the gradual reduction of stocks of weapons-usable neptunium. In Russia, any such benefit is uncertain since additional stocks of neptunium may be separated as a part of ongoing Russian spent fuel reprocessing operations.

Additional Protocol access would not be permitted because of environmental sampling access rights granted to the IAEA under Articles 5, 6 and 9 of the Protocol. However, invasive Additional Protocol access should not be required to provide sufficient transparency to mitigate concerns and uncertainties associated with FDPF.

The Additional Protocol was designed to capture clandestine nuclear weapons program facilities in non-nuclear-weapon states. Since it is well known that FDPF has a long history (the facility is currently non-operational) of Navy defense missions, and since the described mission does not involve the production of special fissionable material (SFM), sufficient transparency would be provided by a managed access regime that would meet the requirements of FMCT verification. *If managed access can be granted to the FDPF, sufficient for verification of an FMCT, the uncertainties and concerns associated with the use of FDPF for the Pu-238 processing mission would be effectively mitigated (with the exception of the material forms technical factor).*

The mitigation approach to improve less favorable U.S. alternatives and options can be addressed unilaterally by the Department. Although it is possible that the issues identified cannot be successfully mitigated, these approaches are recommended if a less favorable U.S. alternative or option is desirable on grounds other than what is immediately most favorable from the nonproliferation perspective.

9.4.2 Russian Purchase Option Mitigation Approach

To help mitigate the uncertainty surrounding Russian ANM domestic safeguards practices, the United States could elect to engage the Russian side through existing programs to both explore and look for opportunities to improve on Russian ANM domestic safeguards practices. *If the United States had sufficient confidence concerning the rigor of Russian controls on ANM, this uncertainty would be effectively mitigated.*

The nonproliferation concerns and uncertainties are associated with the Russian Pu-238 processing mission at Russian processing facilities. The material forms technical factor (the third technical factor) cannot be fully mitigated since neptunium must be separated and purified as part of the Pu-238 processing mission (in a target post-irradiation processing facility). This is always the case and is technically unavoidable. *However, if Russia were to implement a moratorium on spent nuclear fuel reprocessing, this factor would be partially mitigated to "◑ might raise nonproliferation concerns" – similar to the U.S. program assessments.*

Other concerns and uncertainties surrounding the use of a Russian facility are associated with its possible history as a defense programs facility and the resulting potential lack of transparency that could be available in the event that international monitoring becomes desirable under an FMCT. Mitigation of nonproliferation concerns and uncertainties for a Russian facility would require a vulnerability assessment (performed by Russia) to determine the national security risk of a managed access regime that would be required for verification of an FMCT. *If managed access can be granted to the Russian facility, sufficient for verification of an FMCT, the uncertainties and concerns associated with the use of a Russian facility for the Pu-238 processing mission would be effectively mitigated (with the exception of the material forms technical factor).*

Mitigation approaches to improve the alternatives and options involving the Russian purchase option cannot be addressed unilaterally by the Department. Since Russian facilities are involved, U.S.-Russian bilateral arrangements would be required. Nevertheless, the Russian side has been responsive to other U.S. initiatives to help improve Russian nuclear material security. Although it is possible that the issues identified cannot be successfully mitigated, these approaches are recommended if the No Action Alternative (all options) or Alternative 5 (Permanently Deactivate FFTF Without Any New Missions) is desirable on grounds other than what is immediately most favorable from the nonproliferation perspective.

10 APPENDIX

10.1 NONPROLIFERATION CONCEPTS, DEFINITIONS, AND BACKGROUND

10.1.1 Theft and Diversion of Nuclear Materials

The risks of theft and of diversion of nuclear material are fundamentally different in nature. Each type of threat has different origins and is subject to different constraints. Theft can be countered through comprehensive material protection, control, and accounting (MPC&A) programs designed to raise the difficulty of unauthorized access to a level determined to ensure the security of the material. The level of protection and frequency of material accounting is set primarily as a function of the attractiveness of the material from a point of view of theft.

When considering the risk of theft there are two types of adversaries: outsiders and insiders. Of these, the insider threat is the more difficult to counter as insiders may have access to information on MPC&A vulnerabilities as well as the material itself. Furthermore, they may spend considerable time developing methods to defeat MPC&A systems in a way that delays detection. This is a covert approach to theft. Outsider threats can vary from violent overt approaches to covert approaches that enlist the aid of insiders as informants and possibly to assist in penetrating security systems during the commission of a theft.

Material diversion, on the other hand, can be countered only through careful material control and accounting (MC&A) performed by an independent verifying agency such as the International Atomic Energy Agency (IAEA). Through periodic unannounced inventory inspections, or through remote monitoring, IAEA inspectors increase the likelihood that diversion will be detected in a timely manner. Pressure to prevent diversion is applied purely through political means within the international community with timely detection acting as the critical technical link supporting the political process.

Material attractiveness must be defined after determining which threat is under consideration: theft or diversion? In the case of theft, material attractiveness definitions tend to stress the ease of material concealment, movement, and conversion of the material to weaponized form. Adversaries need not have any larger military objectives in mind. Amounts in excess of a significant quantity (SQ) of readily usable fissile material are considered most attractive. Materials that are radioactive or bulky, requiring significant technical processes to produce weapons components, are considered less attractive since they are difficult to conceal and transport and their use requires extensive technical resources.

The interests of a proliferant considering diversion, are significantly different than those of adversaries considering theft. A proliferant that has made a decision to attempt diversion is taking considerable political risk. It is likely that there are significant internal and external political, military, and strategic issues being considered in such a decision. Most often, proliferants view the nuclear option as either the best or only method of achieving critical national security goals in view of their current security environment. Proliferant countries have been willing to spend considerable financial resources on their nuclear weapons programs.

The traditional constraint faced by proliferants has been the scarcity of weapons grade material given that a militarily significant amount of material is usually desired. Given these considerations, it is the amount and quality of the material that will be available to a weapons program that is paramount in the case of national diversion. The degree of technical difficulty in the theft or ease of conversion of the material to weapons use are secondary concerns. However, since the ease of conversion has an immediate impact on whether detection is timely, the IAEA gives due consideration to this factor when judging material attractiveness.

10.1.2 Diversion Risk and the United States: Putting the Threat into Perspective

The IAEA has traditionally not expended significant resources safeguarding civil nuclear fuel cycle facilities in the United States. There is a rational basis for this decision. The IAEA's primary safeguards role is to act as an impediment to horizontal proliferation. Controlling vertical proliferation is the primary focus of the United Nations Conference on Disarmament (CD) and bilateral arms control agreements between nuclear-weapon states. If total nuclear disarmament is achieved the distinction between nuclear and non-nuclear-weapon states would presumably disappear and all States would be treated equally under the Nonproliferation Treaty (NPT).[1] As such, the IAEA is focussing its efforts on full-scope strengthened safeguards in non-nuclear-weapon states and on export/import monitoring – two activities directly germane to preventing horizontal proliferation.[2] Given the large quantities of U.S. defense nuclear materials and active defense programs that are exempt from international safeguards for reasons of national security, it would be a less optimum use of IAEA resources to place significant numbers of voluntarily offered U.S. civil nuclear facilities under international safeguards. Even so, in certain high-profile cases, the IAEA may elect to place a voluntarily offered facility under safeguards either as a confidence building measure (CBM) or if the case involves considerable amounts of U.S. material declared excess to defense needs.[3] In this case, placing the material under international safeguards creates confidence that the material will not be used again in nuclear weapons, thereby reducing vertical proliferation.

To fully understand the reasoning behind the above discussion, it is useful to consider the scope of defense nuclear materials that are stockpiled by the U.S. Government. The U.S. Government has declared 174 metric tons of defense inventory highly enriched uranium (HEU) as excess to defense needs and has placed a significant amount of this material under international safeguards as a CBM. The United States produced 994 metric tons of HEU for defense needs from 1945 through 1992.[4] In addition to HEU, the U.S. Government has declared 52 metric tons of defense inventory plutonium as excess to defense needs and has placed a significant amount of this material under international safeguards as a CBM. The United States produced and acquired 111 metric tons of plutonium for defense needs from 1944 through 1994. Given the scope of these figures, the current and past scope of the U.S. nuclear stockpile, the current aggressive schedule for U.S. nuclear weapon dismantlement, the concept of national diversion from U.S. civil nuclear facilities posing a vertical proliferation threat is not credible. However, the possibility of diversion in non-nuclear-weapon states poses a real and continuing threat of horizontal proliferation, particularly so in regions of proliferation concern.

10.1.3 DOE Safeguards Grades

DOE safeguards are graded on two dimensions: Category and material Attractiveness Level. Category is determined by the amount of special nuclear material of a given Attractiveness Level contained in a facility. Attractiveness Level is determined by the technical difficulty involved in preparing the material for use in a nuclear explosive. Since the technical difficulty of using a particular type of nuclear material

---

[1] Under Article VI of the 1970 NPT, each State party "…undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament…under strict and effective international control." Furthermore in Article I, nuclear weapons States promise to not assist non-weapon States in obtaining nuclear weapons and in Article II, non-nuclear weapons States promise to not receive or develop nuclear weapons.

[2] IAEA INFCIRC/540, 1997, Annex II, "List of Specified Equipment and Non-Nuclear Material for the Reporting of Exports and Imports…" is an example of the IAEA's expanding role in the International Export Control Regime.

[3] For example, the Y-12 HEU storage vault at Oak Ridge, Tennessee; the plutonium storage vault at the Hanford, Washington, site; the plutonium storage vault at Rocky Flats, Colorado; and the BWXT HEU blend-down facility, in Lynchburg, Virginia.

[4] For example, one metric ton is equal to 1,000 kg. Since the IAEA definition of a SQ of HEU is 25 effective kg of U-235, 994 metric tons of HEU represents tens of thousands of SQs of HEU. An SQ is considered by the IAEA to qualitatively estimate the amount of fissile material required to produce a single nuclear explosive.

is somewhat independent of its amount, material Attractiveness Level is determined first, followed by the Category. Since the Category is a function of the amount of material in a material balance area (MBA) or a facility, the Category often becomes associated with the facility. A full description of the DOE material grading and safeguards system is beyond the scope of this assessment. Please refer to *DOE O 474.1, 8-11-99, Control and Accountability of Nuclear Materials (supercedes DOE Order 5633.3b), DOE M 471.1-1, 8-11-99, Manual for Control and Accountability of Nuclear Materials,* and further in the *Guide for Implementation of DOE 5633.3B, "Control and Accountability of Nuclear Materials," April 1995,* for greater detail.

10.1.3.1 DOE MATERIAL ATTRACTIVENESS LEVELS

Attractiveness Level A: Weapons. Weapons and test devices and partially assembled weapons and test devices sufficient to construct an improvised nuclear device using commercially available parts and materials.

Attractiveness Level B: Pure Products. Material that can be used in its existing form or that can be utilized after simple mechanical removal of cladding, packaging, or matrix material to produce a weapon or improvised nuclear device through casting, forming, or other non-chemical operations. For material to be Level B, its total special nuclear material (SNM) content must exceed 50 atom percent. That is, greater than 50% of the atoms present must be SNM.

Attractiveness Level C: High-Grade Materials. Materials that can be easily converted to SNM metal. Generally, these materials are of low bulk and high purity and require relatively little processing time or effort to obtain Level B material (enrichment is not required in the case of uranium). Level C material includes items that yield Level C material upon simple mechanical removal of cladding, packaging, or matrix material.

Attractiveness Level D: Low-Grade Materials. Materials that are more dilute or of lower purity than Level C materials, and require greater processing time or greater processing complexity to convert to metal than Level C materials. Diversion or theft of a large quantity of bulk material is required to obtain an improvised nuclear device quantity of SNM or processing requires extensive precautions for protection against radioactive emissions. Level D includes moderately radioactive materials (between 15 and 100 REM per hour at 1 meter), materials with various intermediate concentrations of plutonium and U-233 and enrichments of U-235, and materials bearing Pu-238 with isotopic composition greater than 20% but less than 60%.

Attractiveness Level E: All Other Materials. Materials that contain SNM but do not meet the requirements to be considered Level D material. Level E includes highly radioactive materials (at or above 100 REM per hour at 1 meter), uranium bearing materials with enrichments less than 20%, and materials bearing Pu-238 with isotopic composition greater than 60%.

10.1.3.2 DOE MATERIAL CATEGORIES

Category I Pu/U-233 materials include all Level A materials, 2 kilogram (kg) or more of Level B materials, and 6 kg or more of Level C materials. Category I U-235/ANM materials include all Level A materials, 5 kg or more of Level B materials, and 20 kg or more of Level C materials.

Category II Pu/U-233 materials include 0.4 kg to 2 kg of Level B materials, 2 kg to 6 kg of Level C materials, and 16 kg or more of Level D materials. Category II U-235/ANM materials include 1 kg to 5 kg of Level B materials, 6 kg to 20 kg of Level C materials, and 50 kg or more of Level D materials.

Category III Pu/U-233 materials include 0.2 kg to 0.4 kg of Level B materials, 0.4 kg to 2 kg of Level C materials, and 3 kg to 16 kg of Level D materials. Category III U-235/ANM materials include 0.4 kg to 1 kg of Level B materials, 2 kg to 6 kg of Level C materials, and 8 kg to 50 kg of Level D materials.

Category IV Pu/U-233 materials include less than 0.2 kg of Level B materials, less than 0.4 kg of Level C materials, less than 3 kg of Level D materials, and any reportable quantity of Level E materials. U-235/ANM materials include less than 0.4 kg of Level B materials, less than 2 kg of Level C materials, less than 8 kg of Level D materials, and any reportable quantity of Level E materials.

10.1.4 Nuclear Regulatory Commission Safeguards Grades

Nuclear Regulatory Commission (NRC) safeguards are graded on a single dimension: Category. Category is determined by the amount of various types of SNM contained in a facility. Since the Category is a function of the amount of material in a MBA or a facility, the Category often becomes associated with the facility. A full description of the NRC material grading and safeguards system is beyond the scope of this assessment. Please refer to *10 CFR 73 and 74 and relevant NUREGs* for greater detail.

Category I amounts of material contain one or more formula quantities of *strategic special nuclear material* (SSNM). SSNM is defined as U-235 in uranium enriched to 20% or more, U-233 and plutonium. A formula quantity of SSNM is defined as 5000 grams calculated as (grams of U-235) + 2.5(grams of U-233 + grams of Pu). Furthermore, Category I is subdivided into two subcategories as follows:
Category IA material has the following characteristics:

1) The dimensions are small enough to hide items on an individual.
2) The total weight of an item (material and matrix) is small enough to be carried inconspicuously by one person.
3) The quantity of SSNM in each item or container is large enough such that a formula quantity can be accumulated in a reasonable number of thefts.

Category IB material is defined as all Category I materials other than Category IA material.

Category II amounts of material contain:

1) Less than a formula quantity but more than 1000 grams of SSNM calculated as (grams of U-235) + 2(grams of U-233 + grams of Pu).
2) Ten kilograms of U-235 contained in uranium enriched to 10% or more but less than 20%.

Category II quantities of materials are referred to as: *special nuclear material of moderate strategic significance.*

Category III amounts of material contain:

1) Less than a Category II amounts of materials but more than 15 grams of U-235 contained in uranium enriched to 20% or more or 15 total grams computed as (grams of U-235) + (grams Pu) + (grams U-233).
2) Less than 10 kg but more than 1 kg of U-235 contained in uranium enriched to 10% or more but less than 20%.
3) Ten kilograms or more of U-235 contained in uranium enriched above natural but less than 10%.

Category III quantities of materials are referred to as: *special nuclear material of low strategic significance.*

Irradiated materials that have a radiological barrier of more than 100 REM per hour at 1 meter can be reduced by one Category while that barrier remains. Fresh Category III materials remain in Category III following irradiation.

10.1.5 Radiological Self-Protection: The Effects of Acute Radiation Exposure on Human Health

The concept of radiological self-protection is central to discussions on theft risk reduction in the case of irradiated materials. In fact, the dose rate of irradiated materials is one of the variables for determination of material attractiveness in most regulatory frameworks covering MPC&A. If a significant radiation barrier is present, the risk of theft is significantly reduced and this is generally taken into account in a graded safeguards system. A radiological barrier that is 100 REM per hour at 1 meter (or greater) is referred to as the "spent fuel standard." The spent fuel standard is discussed in Section 2.

Figure 10.1-1. Effects of Acute Radiation Dose on Human Health

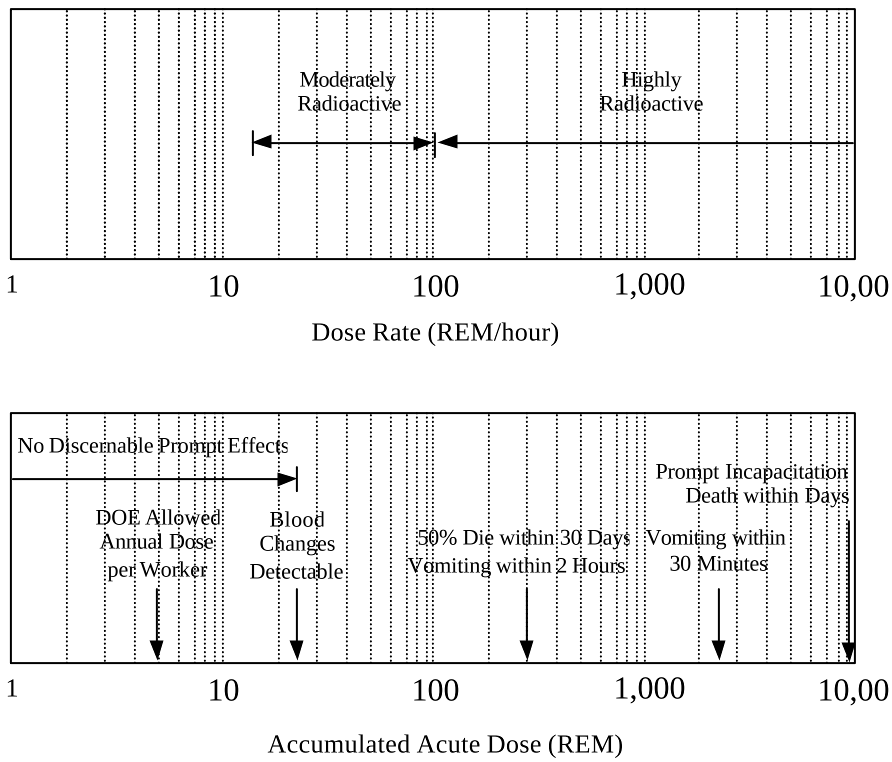

Figure 10.1-1 shows a diagram of acute (or immediate) radiation effects on human health. The figure has two charts: the upper shows the dose rate in REM per hour (radiation exposure per unit time) and the lower shows the accumulated or total acute dose in REM (total radiation exposure).[5] The radioactivity of irradiated materials and spent nuclear fuel is expressed as a dose rate at a given distance (REM per hour at 1 meter), whereas the immediate health effects are related to the accumulated acute dose (REM). Therefore, the immediate health consequence to a person handling radioactive materials depends on the material radioactivity, how long the material is handled, and the distance between the material and the person. Shielding reduces the dose rate at a given distance depending on the shield's ability to absorb radiation, with shield density and thickness being the primary factors. Long-term effects of radiation doses on human health (such as an increase in cancer probabilities) are not shown in Figure 10.1-1 as they are not considered relevant to reduction of theft risk. The immediate health consequences of high doses of whole-body gamma radiation represent a significant barrier to theft of highly radioactive materials, and

[5] REM (Radiation Equivalent in Man) is a radiation dose measurement unit that is indicative of human biological effects of radiation exposure.

this characteristic is one of the major considerations of the Spent Fuel Standard, a concept developed to evaluate the potential proliferation concerns of nuclear materials. Operations involving such materials require heavy shielding and remote handling equipment. The IAEA considers all materials above 100 REM per hour at 1 meter to be self-protected sufficiently to reduce the material attractiveness by one Category.[6] This threshold only allows a few minutes of close contact before noticeable blood changes occur (above 25 REM of acute dose, a blood test will indicate exposure). DOE considers whole body doses above 15 REM per hour at 1 meter to cause a significant reduction in theft risk and 100 REM per hour at 1 meter to essentially rule out theft as a principal risk consideration.[7]

10.1.6 Role of U.S. and International Nuclear Export Controls

The United States seeks to advance nonproliferation objectives by developing and implementing policies, regulations, and procedures to halt the spread of nuclear weapons (and other weapons of mass destruction) and their related technologies. This is done both through U.S. laws and regulations, and multilateral supply arrangements, which control the transfer of nuclear and nuclear-related equipment, materials, and technologies.

Specifically, U.S. nuclear export control policy is governed by a large body of laws, regulations, and international agreements. In general, persons seeking to export nuclear commodities out of the United States must submit an export license application to one of the three controlling U.S. agencies: the Department of Commerce (dual-use equipment), the DOE (nuclear technology), and the Nuclear Regulatory Agency (nuclear equipment).

An export license review is an interagency hierarchical process. Under the December 6, 1995, Executive Order 12981, decisions on the approval or denial of dual-use export license applications will be resolved within 90 days or will be escalated to the President of the United States. Specific lists that are used to make determinations can be found in *15 CFR 773, 10 CFR 810,* and, *10 CFR 110.*

The International Nuclear Export Control Regime is made up principally by the Nonproliferation Treaty Exporters Committee (the Zangger Committee – named after the first Committee Chairman) and the Nuclear Suppliers Group (NSG). Both are multilateral nuclear export control groups made up of the principal industrial nuclear supplier States – Canada, France, Germany, Japan, the United Kingdom, Russia and the United States. Furthermore, China is a member of the Zangger Committee. These groups create and follow export control standards and share information on exports and, in the case of the NSG, export denials. U.S. nuclear export controls are required to be at least as restrictive as the international regime, but may be more restrictive on a unilateral basis if required by Executive decision or by legislation.

Nuclear export controls are a well-developed system with a long history and significant institutional knowledge. Any nuclear exports that might occur under the missions proposed in the Draft NI PEIS would be subject to both U.S. and international nuclear export controls.

[6] International Atomic Energy Agency. *The Physical Protection of Nuclear Material*. INFCIRC/225/Rev. 3. September 1993. Category III material remains in the same (lowest Category) regardless of radiation barrier.
[7] *Guide for Implementation of DOE 5633.3B, "Control and Accountability of Nuclear Materials,"* April 1995.

10.1.7 Additional U.S. Policy, Laws and Regulations, and International Agreements Relevant to this Assessment

The international and domestic legal framework of the nuclear nonproliferation regime is presented in Section 2. Additional elements are presented below.

10.1.7.1 U.S. NONPROLIFERATION AND EXPORT CONTROL POLICY STATEMENT

The White House Office of the Press Secretary released a nonproliferation and export control policy statement on September 27, 1993. In this statement, policy directives covering nuclear nonproliferation received prominent coverage. The 1993 Nonproliferation Policy Statement is reproduced in total in Appendix 10.2. U.S. nuclear nonproliferation policy goals include:

- Indefinite extension of the Nonproliferation Treaty in 1995,
- to assist the IAEA in completing work on the development of an Additional Protocol,
- to lend necessary technical assistance to the IAEA to implement its vital safeguards responsibilities and improve its ability to detect clandestine nuclear activities,
- to take a comprehensive approach to the growing accumulation of fissile materials from dismantled nuclear weapons and civil nuclear programs, including:
  - to seek to eliminate accumulation of stockpiles of HEU and plutonium and ensure their safeguards,
  - to pursue an FMCT,
  - to encourage more restrictive regional arrangements to constrain fissile material production in regions of proliferation risk,
  - to place excess U.S. defense fissile material under IAEA safeguards,
  - to purchase HEU from other countries for conversion to peaceful use as civil reactor fuel,
  - to explore means to limit stockpiling of civil plutonium and minimize the civil use of HEU,
  - to initiate a comprehensive review of long-term plutonium disposition options, and
- initiatives to review and streamline U.S. nonproliferation export controls.

In addition, the U.S. Government stated its position on plutonium reprocessing:

> The United States does not encourage the civil use of plutonium and, accordingly, does not itself engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes. The United States, however, will maintain its existing commitments regarding the use of plutonium in civil nuclear programs in Western Europe and Japan.

This statement has been interpreted strictly. The term “plutonium” in the policy is correctly interpreted as meaning plutonium with a significant fraction of plutonium isotopes other than Pu-238.[8] This definition of plutonium captures the isotopic distribution found in spent nuclear fuel (and spent fertile uranium targets).

10.1.7.2 U.S. LAWS AND REGULATIONS

Selected portions of the large body of U.S. laws and regulations, that would pertain to the missions described in the Draft NI PEIS, that are immediately relevant to this nonproliferation assessment are listed below.

[8] Isotopically concentrated Pu-238 production is not captured by the U.S. reprocessing policy.

Title 42, U.S. Code, Section 2011, et. seq., Atomic Energy Act of 1954, as amended establishes a program for U.S. Government control of the possession, use, export, and production of nuclear energy and SNM, whether owned by the U.S. Government or others.

Schumer Amendment (to the Atomic Energy Act). Under the Schumer Amendment, exports of U.S. HEU fuel for foreign research and test reactors are encumbered by conditions that require conversion of foreign reactors, that are recipients of U.S. HEU fuel, to alternative low enriched uranium (LEU) fuel unless certain exclusion conditions are met:[9]

- An existing research or test reactor can operate using HEU fuel if it can be demonstrated that the reactor can not operate using LEU fuel, or
- the reactor is currently in the process of being converted (or studied for conversion) to LEU fuel but must use HEU fuel until the conversion is complete, or
- the use of LEU fuel would significantly curtail the execution of the reactor's mission, or
- the use of LEU fuel would greatly increase the cost of operating the reactor.

The development and qualification of alternative LEU fuels is the responsibility of the Department's Reduced Enrichment Research and Test Reactor (RERTR) Program. Although there is no legislation that legally requires compliance with the Schumer Amendment by U.S. domestic civil reactors, the civil HEU policy is captured generically within the scope of the 1993 Nonproliferation Policy Statement under the rubric of minimization of the civil use of HEU. To avoid a double standard, the United States seeks to use the Schumer Amendment as a model for its domestic policy agenda regarding the civil use of HEU. As a result, current and future U.S. domestic fuel cycle decisions regarding the civil use of HEU should be compatible with the Schumer Amendment. The Schumer Amendment is reproduced in total in Appendix 10.3.

Title 10, CFR, Part 73 – Physical Protection of Plants and Materials is the NRC regulation governing physical protection measures at NRC facilities. Safeguards grades are defined in the general provisions of the regulation. The regulation covers physical protection for material in transit and at fixed sites. It also covers physical protection against radiological sabotage. 10 CFR Part 73 Appendix E covers physical protection for international transport of nuclear materials. 10 CFR Part 73 is the legal basis for detailed NRC physical protection regulations and procedures (relevant NUREGs).

Title 10, CFR, Part 74 – Material Control and Accounting of Special Nuclear Material is the NRC regulation governing MC&A at NRC facilities. The regulation covers MC&A requirements for three safeguard grades: low strategic significance (Category III), moderate strategic significance (Category II), and strategic special nuclear materials (Category I). 10 CFR Part 74 is the legal basis for detailed NRC MC&A regulations and procedures (relevant NUREGs).

Title 10, CFR, Part 75 – Safeguards on Nuclear Material – Implementation of US/IAEA Agreement is the NRC regulation governing implementation of the U.S. Voluntary Offer. The regulation creates the legal basis for detailed NRC regulations and procedures to comply with the terms of the U.S. Voluntary Offer at NRC facilities.

Title 10, CFR, Part 110 – Export and Import of Nuclear Equipment and Material is the NRC regulation covering NRC nuclear export control responsibilities.

Title 10, CFR, Part 810 – is the DOE regulation covering DOE nuclear export control responsibilities.

[9] LEU is defined as U-235 enrichments below 20%.

Title 15, CFR, Part 773, 776, 778, 779, 785 and 799 is the primary body of Federal regulation covering U.S. Department of Commerce nuclear export control responsibilities under the **Export Administration Act of 1979, as amended.**

10.1.7.3 DEPARTMENT OF ENERGY ORDERS

DOE Order 470.1 – Safeguards and Security Program ensures appropriate levels of protection against unauthorized access; theft, diversion, loss of custody, or destruction of nuclear weapons, or weapons components; espionage; loss or theft of classified matter or Government property; and other hostile acts that may cause unacceptable adverse impacts on national security or on the health and safety of DOE and contractor employees, the public, or the environment.

DOE Order 1270.2B – Safeguards Agreement with the International Atomic Energy Agency is the DOE implementing order for INFCIRC/288, the U.S. Voluntary Offer. This order creates the legal basis within the DOE complex to comply with the terms of the U.S. Voluntary Offer and provides a list of references that describe the detailed orders and documents to carry out compliance with the U.S. Voluntary Offer. The order also provides a list of legal definitions, a summary of the policy and objectives of the Order, a description of responsibilities within the DOE chain of command, and procedures for adding and deleting DOE facilities from the list of eligible facilities under the U.S. Voluntary Offer.

DOE Order 5610.14 – Transportation Safeguards System Program Operations establishes Department of Energy policies for and implementation of the management and operation of the Transportation Safeguards System (TSS) Program.

DOE Order 5632.1C – Protection and Control of Safeguards and Security Interests establishes policy, responsibilities, and authorities for the protection and control of safeguards and security interests (*e.g.*, special nuclear material, vital equipment, classified matter, property, facilities, and unclassified irradiated reactor fuel in transit). See also *DOE M 5632.1C-1, Manual for Protection and Control of Safeguards and Security Interests,* which provides greater detail on requirements for the protection and control of safeguards and security interests plus a full list of references to other legal source documents. In addition, safeguards requirements for ANM are prescribed in *"Protection of Separated Neptunium-237 and Americium," memorandum to distribution from E.J. McCallum, DOE Office of Safeguards and Security, Germantown, MD, February 11, 1999.* The Department treats neptunium and americium as the equivalent of U-235 for the purposes of safeguards and security. As such, materials with significant concentrations and quantities of neptunium and americium are treated identical with respect to physical protection and accounting as SNM.

DOE Order 474.1 – Control and Accountability of Nuclear Materials prescribes the Department of Energy minimum requirements and procedures for control and accountability of nuclear materials at DOE-owned and -leased facilities and DOE-owned nuclear materials at other facilities that are exempt from licensing by the NRC. See also *DOE M 474.1-1, Manual for Control and Accountability of Nuclear Materials* and *DOE G 474.1-1, Guide for Implementation of DOE 5633.3B, "Control and Accountability of Nuclear Materials," April 1995,* (the new *Guide* is not yet available) for greater detail on requirements for DOE MPC&A practices.

DOE Order 5660.1B – Management of Nuclear Materials establishes requirements and procedures for the management of nuclear materials within the Department of Energy.

10.1.7.4 INTERNATIONAL AGREEMENTS

Selected international agreements, that would pertain to the missions described in the Draft NI PEIS and that are immediately relevant to this nonproliferation assessment, are listed below. Further discussion of the

The Nonproliferation Treaty (NPT). The *Treaty on the Nonproliferation of Nuclear Weapons* entered into force in 1970. The NPT requires that nuclear-weapon state parties (China, France, Russia, the United Kingdom, and the United States) must not assist non-nuclear-weapon state parties in acquiring nuclear explosives and must pursue negotiations to end the nuclear arms race and achieve complete nuclear disarmament. Non-nuclear-weapon state parties must not acquire nuclear explosives, must not seek assistance in acquiring nuclear explosives and must accept international safeguards on all nuclear activities. In return, non-nuclear-weapon state parties have the right to pursue peaceful nuclear energy without discrimination and can trade in nuclear equipment and materials subject to international safeguards. The IAEA, which is an autonomous part of the United Nations, is the international body that oversees NPT compliance and inspects safeguarded facilities. The IAEA also acts in a role promoting international nuclear safety, regulatory guidelines, and nuclear technology information.

International Physical Protection Convention and International Safeguards. International physical protection standards for international transportation are described in *The Convention on the Physical Protection of Nuclear Material,* IAEA INFCIRC/274, 1997, and further in *The Physical Protection of Nuclear Material,* IAEA INFCIRC/225, 1999. International safeguards are described in *The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons,* IAEA INFCIRC/153, 1972. Strengthened International Safeguards are described in the *Model Protocol Additional to the Agreement(s) Between State(s) and the International Atomic Energy Agency for the Application of Safeguards*, IAEA INFCIRC/540, September 1997. Any special fissionable material (SFM) imported to the United States, as a result of missions described in the Draft NI PEIS (*e.g.,* German mixed oxide [MOX] fuel), from a non-nuclear weapons State would be subject to the specific Safeguards Agreements in force. These specific agreements are based on the generic models in INFCIRC/153 and INFCIRC/540.

U.S.-EURATOM Agreement for Cooperation. If German MOX fuel is imported to the United States the material will be subject to the *Agreement for Cooperation in the Peaceful Uses of Nuclear Energy Between the United States of America and the European Atomic Energy Community (EURATOM)*, date of agreement effect April 12, 1996. The agreement for cooperation requires that relevant Safeguards Agreements remain in effect (*e.g.,* U.S. Voluntary Offer, etc.), that imported materials are restricted to peaceful uses, that physical protection is applied to imported materials, and that the United States will make an annual accounting report to EURATOM of all SFM of EURATOM origin that are in U.S. custody.

10.2 NONPROLIFERATION AND EXPORT CONTROL POLICY STATEMENT

THE WHITE HOUSE

Office of the Press Secretary

For Immediate Release September 27, 1993

FACT SHEET
NONPROLIFERATION AND EXPORT CONTROL POLICY

The President today established a framework for U.S. efforts to prevent the proliferation of weapons of mass destruction and the missiles that deliver them. He outlined three major principles to guide our nonproliferation and export control policy:

-- Our national security requires U.S. to accord higher priority to nonproliferation, and to make it an integral element of our relations with other countries.

-- To strengthen U.S. economic growth, democratization abroad and international stability, we actively seek expanded trade and technology exchange with nations, including former adversaries, that abide by global nonproliferation norms.

-- We need to build a new consensus — embracing the Executive and Legislative branches, industry and public, and friends abroad — to promote effective nonproliferation efforts and integrate our nonproliferation and economic goals.

The President reaffirmed U.S. support for a strong, effective nonproliferation regime that enjoys broad multilateral support and employs all of the means at our disposal to advance our objectives.

Key elements of the policy follow.

<u>Fissile Material</u>

The U.S. will undertake a comprehensive approach to the growing accumulation of fissile material from dismantled nuclear weapons and within civil nuclear programs. Under this approach, the U.S. will:

-- Seek to eliminate where possible the accumulation of stockpiles of highly-enriched uranium or plutonium, and to ensure that where these materials already exist they are subject to the highest standards of safety, security, and international accountability.

-- Propose a multilateral convention prohibiting the production of highly-enriched uranium or plutonium for nuclear explosives purposes or outside of international safeguards.

-- Encourage more restrictive regional arrangements to constrain fissile material production in regions of instability and high proliferation risk.

-- Submit U.S. fissile material no longer needed for our deterrent to inspection by the International Atomic Energy Agency.

-- Pursue the purchase of highly-enriched uranium from the former Soviet Union and other countries and its conversion to peaceful use as reactor fuel.

-- Explore means to limit the stockpiling of plutonium from civil nuclear programs, and seek to minimize the civil use of highly-enriched uranium.

-- Initiate a comprehensive review of long-term options for plutonium disposition, taking into account technical, nonproliferation, environmental, budgetary and economic considerations. Russia and other nations with relevant interests and experience will be invited to participate in this study.

The United States does not encourage the civil use of plutonium and, accordingly, does not itself engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes. The United States, however, will maintain its existing commitments regarding the use of plutonium in civil nuclear programs in Western Europe and Japan.

Export Controls

To be truly effective, export controls should be applied uniformly by all suppliers. The United States will harmonize domestic and multilateral controls to the greatest extent possible. At the same time, the need to lead the international community or overriding national security or foreign policy interests may justify unilateral export controls in specific cases. We will review our unilateral dual-use export controls and policies, and eliminate them unless such controls are essential to national security and foreign policy interests.

We will streamline the implementation of U.S. nonproliferation export controls. Our system must be more responsive and efficient, and not inhibit legitimate exports that play a key role in American economic strength while preventing exports that would make a material contribution to the proliferation of weapons of mass destruction and the missiles that deliver them.

Nuclear Proliferation

The U.S. will make every effort to secure the indefinite extension of the Non-Proliferation Treaty in 1995. We will seek to ensure that the International Atomic Energy Agency has the resources needed to implement its vital safeguards responsibilities, and will work to strengthen the IAEA’s ability to detect clandestine nuclear activities.

Missile Proliferation

We will maintain our strong support for the Missile Technology Control Regime. We will promote the principles of the MTCR Guidelines as a global missile nonproliferation norm and seek to use the MTCR as a mechanism for taking joint action to combat missile proliferation. We will support prudent expansion of the MTCR s membership to include additional countries that subscribe to international nonproliferation standards, enforce effective export controls and abandon offensive ballistic missile programs. The United States will also promote regional efforts to reduce the demand for missile capabilities.

The United States will continue to oppose missile programs of proliferation concern, and will exercise particular restraint in missile-related cooperation. We will continue to retain a strong presumption of denial against exports to any country of complete space-launch vehicles or major components.

The United States will maintain its general policy of not supporting the development or acquisition of space-launch vehicles in countries outside the MTCR.

For MTCR member countries, we will not encourage new space-launch vehicle programs, which raise questions on both nonproliferation and economic viability grounds. The United States will, however, consider exports of MTCR-controlled items to MTCR member countries for peaceful space launch programs on a case-by-case basis. We will review whether additional constraints or safeguards could reduce the risk of misuse of space launch technology. We will seek adoption by all MTCR partners of policies as vigilant as our own.

Chemical and Biological Weapons

To help deter violations of the Biological Weapons Convention, we will promote new measures to provide increased transparency of activities and facilities that could have biological weapons applications. We call on all nations — including our own — to ratify the Chemical Weapons Convention quickly so that it may enter into force by January 13, 1995. We will work with others to support the international Organization for the Prohibition of Chemical Weapons created by the Convention.

Regional Nonproliferation Initiatives

Nonproliferation will receive greater priority in our diplomacy, and will be taken into account in our relations with countries around the world. We will make special efforts to address the proliferation threat in regions of tension such as the Korean peninsula, the Middle East and South Asia, including efforts to address the underlying motivations for weapons acquisition and to promote regional confidence-building steps.

In Korea, our goal remains a non-nuclear peninsula. We will make every effort to secure North Korea’s full compliance with its nonproliferation commitments and effective implementation of the North-South denuclearization agreement.

In parallel with our efforts to obtain a secure, just, and lasting peace in the Middle East, we will promote dialogue and confidence-building steps to create the basis for a Middle East free of weapons of mass destruction. In the Persian Gulf, we will work with other suppliers to contain Iran s nuclear, missile, and CBW ambitions, while preventing reconstruction of Iraq s activities in these areas. In South Asia, we will encourage India and Pakistan to proceed with multilateral discussions of nonproliferation and security issues, with the goal of capping and eventually rolling back their nuclear and missile capabilities.

In developing our overall approach to Latin America and South Africa, we will take account of the significant nonproliferation progress made in these regions in recent years. We will intensify efforts to ensure that the former Soviet Union, Eastern Europe, and China do not contribute to the spread of weapons of mass destruction and missiles.

Military Planning and Doctrine

We will give proliferation a higher profile in our intelligence collection and analysis and defense planning, and ensure that our own force structure and military planning address the potential threat from weapons of mass destruction and missiles around the world.

Conventional Arms Transfers

We will actively seek greater transparency in the area of conventional arms transfers and promote regional confidence-building measures to encourage restraint on such transfers to regions of instability. The U.S. will undertake a comprehensive review of conventional arms transfer policy, taking into account national security, arms control, trade budgetary and economic competitiveness considerations.

10.3 THE SCHUMER AMENDMENT

H12103
October 5, 1992

CONGRESSIONAL RECORD - HOUSE

CONFERENCE REPORT ON H. R. 776.
COMPREHENSIVE NATIONAL ENERGY POLICY ACT

* * *

TITLE IX – UNITED STATES ENRICHMENT CORPORATION

* * *

SEC. 903. RESTRICTIONS ON NUCLEAR EXPORTS

(a) **FURTHER RESTRICTIONS. –**

(1) **IN GENERAL. –** Chapter 11 of the Atomic Energy Act of 1954 (42 U.S.C. 2151 et seq.) is amended by adding at the end the following new section:

"SEC. 134. FURTHER RESTRICTIONS ON EXPORTS. –

"a. The Commission may issue a license for the export of highly enriched uranium to be used as a fuel or target in a nuclear research or test reactor only if, in addition to any other requirement of this Act, the Commission determines that—

"(1) there is no alternative nuclear reactor fuel or target enriched in the isotope 235 to a lesser percent than the proposed export, that can be used in the reactor;

"(2) the proposed recipient of that uranium has provided assurances that, whenever an alternative nuclear reactor fuel or target can be used in that reactor, it will use that alternative in lieu of highly enriched uranium; and

"(3) the United States Government is actively developing an alternative nuclear reactor fuel or target that can be used in that reactor.

"b. As used in this section—

"(1) the term 'alternative nuclear reactor fuel or target' means a nuclear reactor fuel or target which is enriched to less than 20 percent in the isotope U-235;

"(2) the term 'highly enriched uranium' means uranium enriched to 20 percent or more in the isotope U-235; and

"(3) a fuel or target 'can be used' in a nuclear research or test reactor if –

"(A) the fuel or target has been qualified by the Reduced Enrichment Research and Test Reactor Program of the Department of Energy, and

"(B) use of the fuel or target will permit the large majority of ongoing and planned experiments and isotope production to be conducted in the reactor without a large percentage increase in the total cost of operating the reactor."

(2) **CLERICAL AMENDMENT. –** The table of contents of the Atomic Energy Act of 1954 is amended by adding at the end of the items relating to Chapter 11 the following new item:

"Sec 134. Further restrictions on exports."

(b) REPORT TO CONGRESS. –

(1) **IN GENERAL. –** Not later than 90 days after the enactment of this Act, the Chairman of the Nuclear Regulatory Commission, after consulting with other relevant agencies, shall submit to the Congress a report detailing the current disposition Of previous United States exports of highly enriched uranium, including –

(A) their location;

(B) whether they are irradiated;

(C) whether they have been used for the purpose stated in their export license; and

(D) whether they have been used for an alternative purpose and, if so, whether such alternative purpose has been explicitly approved by the Commission.

(2) **EXPORTS TO EURATOM** – To the maximum extent possible, the report required by paragraph (1) shall include –

(A) exports of highly enriched uranium to EURATOM; and

(B) subsequent retransfers of such material within EURATOM, without regard to the extent of United States control over such retransfers.

10.4 PRELIMINARY ASSESSMENT OF BREEDING CAPABILITY OF THE FAST FLUX TEST FACILITY

August 17, 2000
Argonne National Laboratory

One of the nonproliferation issues raised in connection with the restart of the Fast Flux Test Facility (FFTF) is the potential to "breed" plutonium. In its standard configuration, FFTF is not even close to behaving as a breeder reactor (see below). However, operation in a fast neutron energy spectrum produces excess neutrons, which create the potential for net breeding of fissile material – *if* these neutrons are captured in uranium-238. The purpose of this brief analysis is to evaluate whether configuration changes to FFTF would allow breeding and what magnitude of modifications would be required.

10.4.1 Breeding Characteristics of Standard Configurations

Core performance was evaluated using state-of-the-art fast reactor computational tools developed at ANL. Specifically, the REBUS-3 fuel cycle code was used to model the FFTF geometry and material configurations; multigroup cross sections based on ENDF/B-V were employed in the REBUS-3 calculations. A three-batch fuel management strategy with a 138 day cycle length (average driver burnup of 65 MWd/kg) was assumed for all fueled assemblies (drivers and blankets).

First, the breeding behavior of a typical FFTF configuration was evaluated. The standard configuration utilized in this evaluation is shown in Figure 10.4-1. This configuration includes nine experimental locations in the core interior (these were allocated as three Materials Open Test Assemblies and six shim assemblies in previous FFTF operations) and nine control rods. The breeding characteristics using enriched uranium and plutonium oxide and metal fuel are summarized in Table 10.4-1. The breeding ratio is defined as the cycle-averaged ratio of the fissile production rate to the fissile destruction rate; with U-235, Pu-239 and Pu-241 being the fissile isotopes in this analysis. The breeding ratio is quite low for the enriched uranium cases: 0.23 with oxide fuel and 0.29 with metal fuel. Because there is no plutonium present in the initial fuel, ~30 kg/year are produced. For the plutonium based fuel, the breeding ratio is higher (0.4-0.5) but still far from breeding; the plutonium produces more excess neutrons than U-235 in a fast spectrum. With the plutonium enriched fuel, there is a net destruction of 40-55 kg/year of plutonium.

Table 10.4-1. Breeding Characteristics of Standard FFTF Configuration

		Oxide Fuel		Metal Fuel	
Fuel Type		UO_2	U/PuO_2	U-10Zr	U/Pu-10Zr
Fuel Enrichment, %	Inner Zone	30	23	24.5	18
	Outer Zone	37	28.5	30	22
Breeding Ratio		0.231	0.403	0.291	0.498
Net Plutonium Gain (kg/year)		28	-54	34	-42.5

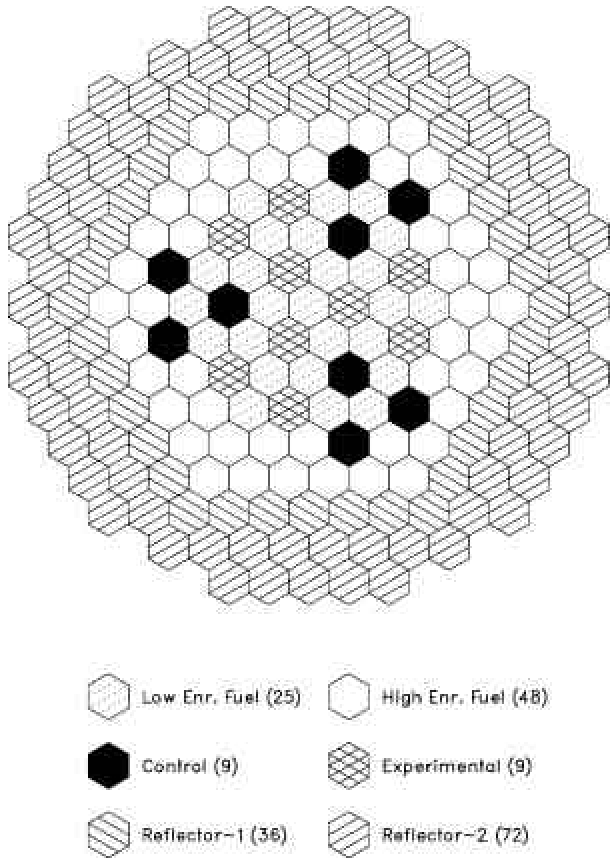

Figure 10.4-1. Typical Fast Flux Test Facility Configuration

10.4.2 Achievable Breeding with Blankets in FFTF

In this section, the breeding characteristics are evaluated for a “fully” blanketed configuration where depleted uranium blankets are allocated to completely surround the FFTF core; the driver configuration shown in Figure 10.4-1 is retained. The nine experimental positions are replaced with internal blankets and both reflector types are also replaced completely with blanket assemblies. In addition, axial blankets are placed directly above and below the enriched fuel zone with a 30 cm height for the upper and lower blankets. To enhance their breeding capacity, the blanket assemblies utilize a very tight lattice with nearly touching pins (P/D ~1.08). For this analysis, a high fuel volume fraction of 52.5% (as obtained in the ALMR blanket design) was assumed for all blanket zones. Note that this approach would require separate pin bundles for the axial blankets within the driver assembly. The standard approach is to include the axial blanket material within the same fuel pin as the enriched driver fuel (referred to as integral axial blankets); this would reduce the fuel volume fraction (and breeding capacity) of the axial blankets as discussed below.

Results are summarized in Table 10.4-2 for the metal fuel cases. The ternary metal fuel case achieves a total breeding ratio of 1.2 and a net production of 36 kg/year of plutonium (as compared to 250 kg/y for a large LWR). This case is indicative of the maximum breeding potential. This core would use modified assemblies in every FFTF grid location except the control rods. Allocation of the axial blanket is particularly problematic. Introduction of separate axial blanket pin bundles would impact coolant flow in the drivers and necessitate a significant re-design of the driver assembly. Alternately, incorporation of integral axial blankets is difficult because of the low fuel smear density and significant fuel axial expansion characteristic of metal fuel. Thus, this high breeding configuration would be *very* difficult to realize in practice.

The breeding contribution of each blanket zone is also indicated in Table 10.4-2. The nine internal blankets contribute ~0.15 to the total breeding ratio of 1.2. The radial blankets contribute 0.44 of which ~0.31 comes from the first row (replacement of the Type I reflectors in Fig. 1) and only ~0.13 from the outer reflector positions. In a similar manner, the first 15 cm of the axial blanket contributes 0.13 of the 0.19 total contribution. Scoping results indicate that the axial blanket breeding component decreases by ~20% if integral axial blankets are used and decreases by ~15% if depleted uranium oxide is substituted for the depleted uranium metal.

Table 10.4-2. Breeding Characteristics of Fully-Blanketed FFTF Configuration.

<table>
<tr><th colspan="2"></th><th>Ternary Metal
U/Pu-10Zr</th><th>Binary Metal
U-10Zr</th></tr>
<tr><td rowspan="2">Fuel
Enrichment, %</td><td>Inner Zone</td><td>19</td><td>27</td></tr>
<tr><td>Outer Zone</td><td>23</td><td>33</td></tr>
<tr><td rowspan="4">Breeding Ratio</td><td>Driver</td><td>0.421</td><td>0.241</td></tr>
<tr><td>Internal Blanket</td><td>0.147</td><td>0.103</td></tr>
<tr><td>Axial Blanket</td><td>0.193</td><td>0.142</td></tr>
<tr><td>Radial Blanket</td><td>0.437</td><td>0.314</td></tr>
<tr><td colspan="2">Total Breeding Ratio</td><td>1.198</td><td>0.799</td></tr>
<tr><td colspan="2">Net Plutonium Gain (kg/year)</td><td>36</td><td>91</td></tr>
</table>

For the enriched uranium metal case, a total breeding ratio of 0.8 is observed for the fully blanketed configuration. This indicates that it is *virtually impossible to achieve net fissile breeding* (breeding ratio > 1) *using enriched uranium fuel*; conversion to plutonium based fuel, with its improved neutron economy, would be required. The uranium fuel does, however, allow a much larger net increase in the plutonium inventory.

10.4.3 Performance of Breeder Configurations

Based on the results of the previous section, near breeder configurations (breeding ratio ~1) were developed for ternary metal and mixed oxide fuel cases and the performance was compared to the standard FFTF configuration. Results are summarized in Table 10.4-3. For the metal fuel, the nine experimental locations and all the reflector positions in FFTF are replaced with blanket assemblies. Because of its lower density, additional external blanket material is needed in the MOX case, so a 30 cm axial blanket is allocated and only the first row of radial blanket is needed.

Results in Table 10.4-3 indicate that a slight enrichment increase (~1%) is needed for the breeder configurations; driver leakage increases when the reflectors are replaced with blankets. In addition, the power peaking performance is degraded with peak power levels rising by about 5%. These design and performance changes could likely be accommodated (*e.g.*, the slight enrichment change needed to maintain criticality). However, the major impact on performance is a large increase in the mass flow rates. With a fuel management strategy similar to the drivers (three batch operation on a 138 day cycle), the heavy metal loading rate for the blanket regions is ~3.5 times larger than the driver loading rate. This implies that significant fuel fabrication capability will be needed to supply the depleted uranium blanket pins and associated assembly hardware.

Table 10.4-3. Performance Comparison of Standard and Breeder FFTF Configurations.

		Mixed Oxide		Ternary Metal	
Fuel Enrichment, %	Inner Zone	23	24	18	19
	Outer Zone	28.5	29.5	22	23
# of IB Assemblies		0	9	0	9
# of RB Assemblies		0	36	0	**108**
Axial blanket thickness, cm		0	**30**	0	0
Breeding Ratio	Driver	0.403	0.340	0.498	0.415
	Internal Blanket	-	0.156	-	0.151
	Axial Blanket	-	0.184	-	-
	Radial Blanket	-	0.303	-	0.461
Total Breeding Ratio		0.403	0.983	0.498	1.027
Net Plutonium Gain (kg/year)		-54	16	-42.5	17
Heavy Metal Loading, kg/y	Driver	1652	1653	2171	2171
	Blankets	-	**5246**	-	**7683**
Power Peaking Factor	BOEC	1.453	1.501	1.430	1.508
	EOEC	1.420	1.465	1.402	1.478

10.4.4 Summary of Results

Preliminary analyses were conducted to evaluate the impact of design changes to increase the breeding ratio of the FFTF core. Key results are:

- The breeding ratio of the standard configuration is quite low ranging from 0.23 for enriched uranium oxide to 0.50 for ternary metal fuel.
- To achieve a breeding ratio greater than 1 in FFTF, conversion from U-235 to plutonium-enriched fuel would be required.
- Large throughputs of blanket material (more than three times the driver mass loading rates) would have to be fabricated and irradiated to achieve net breeding.
- Only with ternary metal fuel can marginal breeding be achieved without axial blankets; introduction of axial blankets would greatly complicate the design and fabrication of the driver fuel assemblies.

Finally, it is important to note the distinction between fissile "breeding" and net plutonium production. A breeding ratio of 1.0 indicates that the fissile inventory of the core is maintained (*i.e.*, no net gain of fissile material). Thus, with plutonium-enriched fuel, FFTF *consumes* 50 kg/year of plutonium in its standard (breeding ratio ~0.45) configuration, and would only have a net production of 15 kg/year in the "breeder" configuration. Conversely, the fully blanketed enriched uranium core has a breeding ratio of only 0.8, yet exhibits the highest net plutonium production rate of 91 kg/year. This rate is much lower than the 250 kg/year of plutonium produced in a once through 1000 MWe LWR. On the other hand, generation of the plutonium in low burnup blankets (which could be introduced surrounding *any* neutron source) yields a low Pu-240 isotopic content and low self-generated radiation field compared to plutonium contained in conventional spent fuel.

10.5 LIST OF ACRONYMS

AEC	Atomic Energy Commission
ALMR	Advanced Liquid Metal Reactor
ANM	Alternate nuclear material (neptunium, americium)
ATR	Advanced Test Reactor
ATW	Accelerator Transmutation of Waste
CBM	Confidence building measure
CD	Conference on Disarmament
CLWR	Commercial light water reactor
DOE	Department of Energy
EURATOM	European Atomic Energy Community
FDPF	Fluorinel Dissolution Process Facility
FFTF	Fast Flux Test Facility
FMCT	Fissile Material Cutoff Treaty
FMEF	Fuels and Materials Examination Facility
FSV	Flow sheet verification
FY	Fiscal year
HEU	Highly enriched uranium
HFIR	High Flux Isotope Reactor
IAEA	International Atomic Energy Agency
IFR	Integral Fast Reactor
LANL	Los Alamos National Laboratory
LEU	Low enriched uranium
LMFBR	Liquid metal fast breeder reactor
LMFR	Liquid metal fast reactor
LWR	Light water reactor
MA	Minor actinides (typically neptunium, americium, curium)
MBA	Material balance area
MC&A	Material control and accounting
MOX	Mixed oxide fuel
MPC&A	Material protection, control, and accounting
MWe	Megawatts electric
MWt	Megawatts thermal
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Protection Act
NERAC	Nuclear Energy Advisory Committee
NGO	Non-government organization
NI NIA	Nuclear Infrastructure Nonproliferation Impact Assessment (this document)
NI PEIS	Nuclear Infrastructure Programmatic Environmental Impact Statement
NPT	Nonproliferation Treaty
NRC	Nuclear Regulatory Commission
PET	Positron emission tomography
PUREX	Plutonium uranium redox extraction
R&D	Research and development
REDC	Radiochemical Engineering Development Center
REM	Radiation Equivalent Man
RERTR	Reduced Enrichment Research and Test Reactor
ROD	Record of Decision

SFM	Special fissionable material
SGT	Safeguarded Transport
SM	Source material
SNM	Special nuclear material
SRS	Savannah River Site
SST	Safe-Secure Trailer
SQ	Significant quantity
TRIGA	Training, research, isotope, General Atomics
TRU	Transuranic elements (typically neptunium, plutonium, americium, curium)
TRUEX	Transuranic extraction
TSS	Transportation Safeguards System
UN	United Nations